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Did an exploding star make our Solar System?

Welcome to issue 70!

The nights are darker, and we at **All About Space** are looking forward to fully resuming our observations of the heavens. We'll be taking in a wide selection of galaxies and star clusters, whilst returning to our firm favourites of the Solar System - in particular, the lunar surface as the Moon wheels through its phases, and the planets as they make their way along the ecliptic at varying times throughout the longer, cooler evenings. Some of you, I know, have recently been purchasing new equipment for that upgrade that'll deliver better views of your favourite targets, whilst others have been setting their sights on replacing their instruments. If you're looking for your next scope but aren't sure where to start, then turn to page 74 for our full guide to choosing the ideal one for you. Whether you're a beginner or seasoned astronomer and whatever your budget, we've got everything you need to make the right decision this season.

On the cloudy evenings, we've got plenty to keep you occupied this issue as we chat to the astronomer who has discovered a new kind of star, meet the astrophysicists who are challenging Einstein's theories and think we need to break space-time to make sense of the universe and find out what else - other than diamond rain - exists under the mysterious cloud covers of Uranus and Neptune. This month, you can also take our tests to find out if you have what it takes to be an astronaut. Drop me a line and let me know how you scored!

Gemma Lavender
Editor

> "In the case of our solar nebula, a nearby supernova shock wave could have rattled our future home" **page 38**

Our contributors include...

Colin Stuart
Royal Observatory Greenwich astronomer & author
Was Einstein wrong? Colin meets the astrophysicists who have broken space-time apart to make more sense of the universe.

Rebecca Caddy
Science and technology writer
Think you've got what it takes to be an astronaut? Rebecca puts you through your paces with some mental agility tests and how to get into space.

Kulvinder Singh Chadha
Space science writer & editor
Recently, planetary scientists have uncovered more about Uranus and Neptune than before – Kulvinder has the details.

Robin Hague
Science and technology writer
Robin uncovers more about Asgardia, a proposed space nation that is currently recruiting citizens. Turn to page 60 to find out more.

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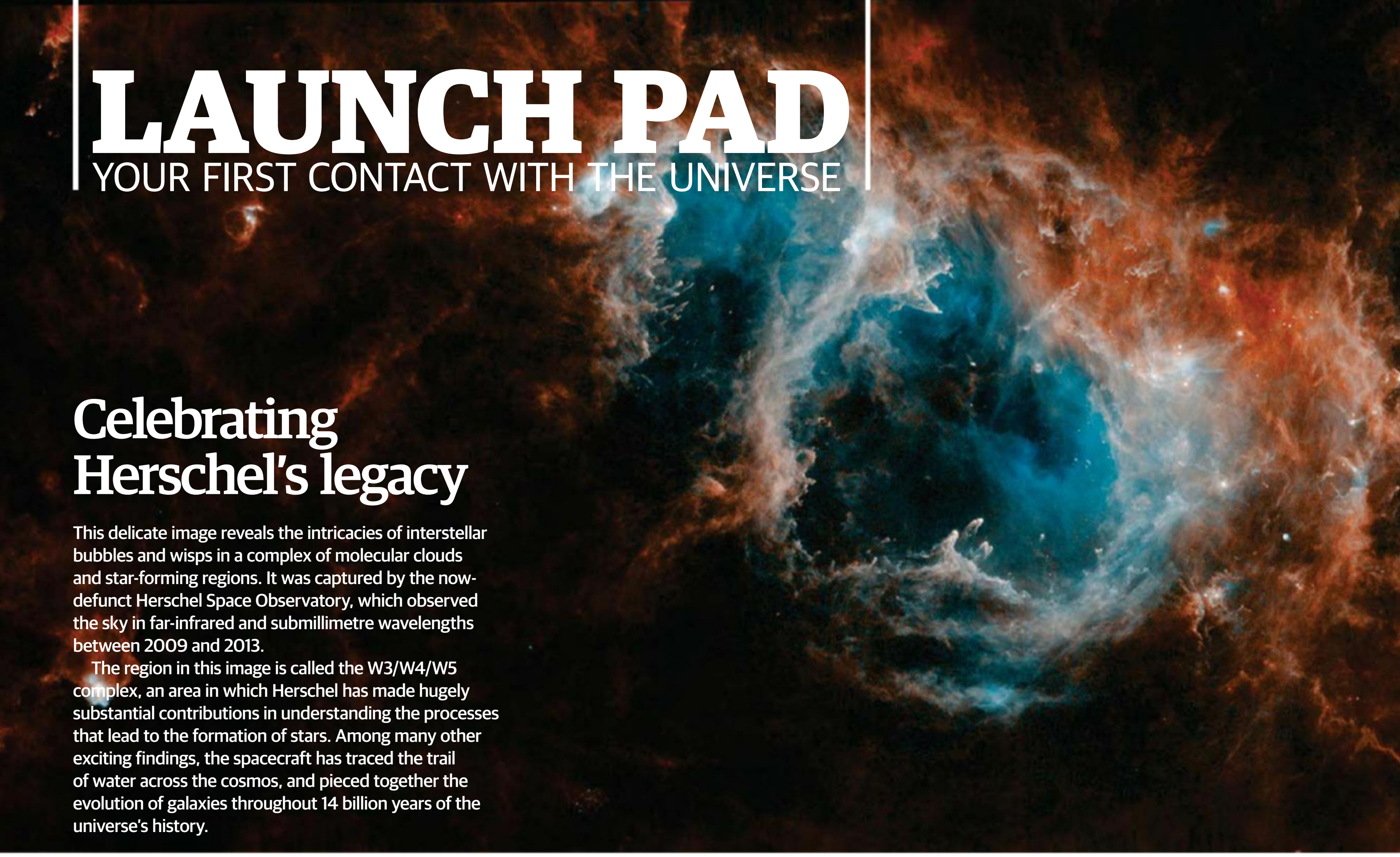
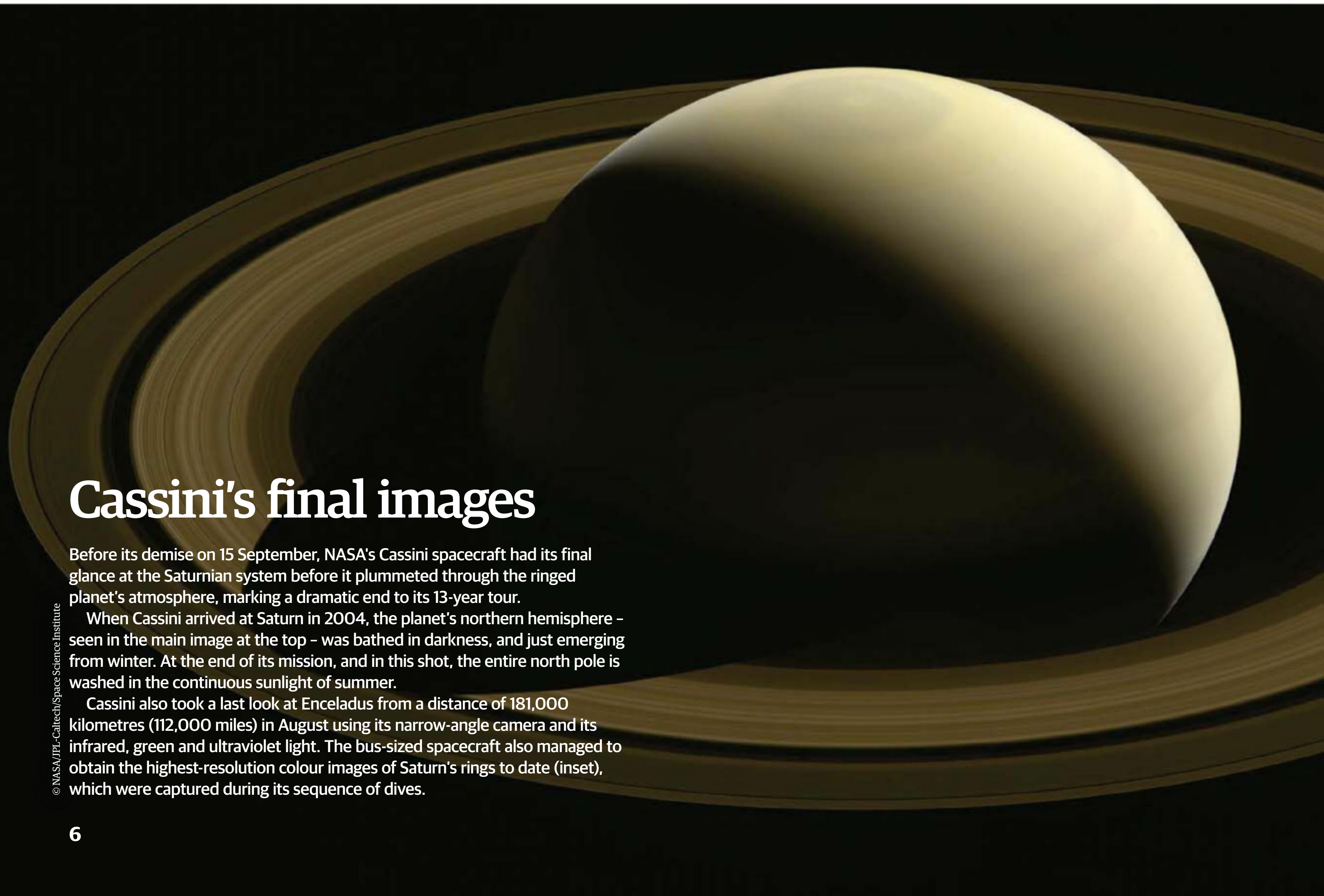


Celebrating Herschel's legacy

This delicate image reveals the intricacies of interstellar bubbles and wisps in a complex of molecular clouds and star-forming regions. It was captured by the now-defunct Herschel Space Observatory, which observed the sky in far-infrared and submillimetre wavelengths between 2009 and 2013.

The region in this image is called the W3/W4/W5 complex, an area in which Herschel has made hugely substantial contributions in understanding the processes that lead to the formation of stars. Among many other exciting findings, the spacecraft has traced the trail of water across the cosmos, and pieced together the evolution of galaxies throughout 14 billion years of the universe's history.



Cassini's final images

Before its demise on 15 September, NASA's Cassini spacecraft had its final glance at the Saturnian system before it plummeted through the ringed planet's atmosphere, marking a dramatic end to its 13-year tour.

When Cassini arrived at Saturn in 2004, the planet's northern hemisphere – seen in the main image at the top – was bathed in darkness, and just emerging from winter. At the end of its mission, and in this shot, the entire north pole is washed in the continuous sunlight of summer.

Cassini also took a last look at Enceladus from a distance of 181,000 kilometres (112,000 miles) in August using its narrow-angle camera and its infrared, green and ultraviolet light. The bus-sized spacecraft also managed to obtain the highest-resolution colour images of Saturn's rings to date (inset), which were captured during its sequence of dives.

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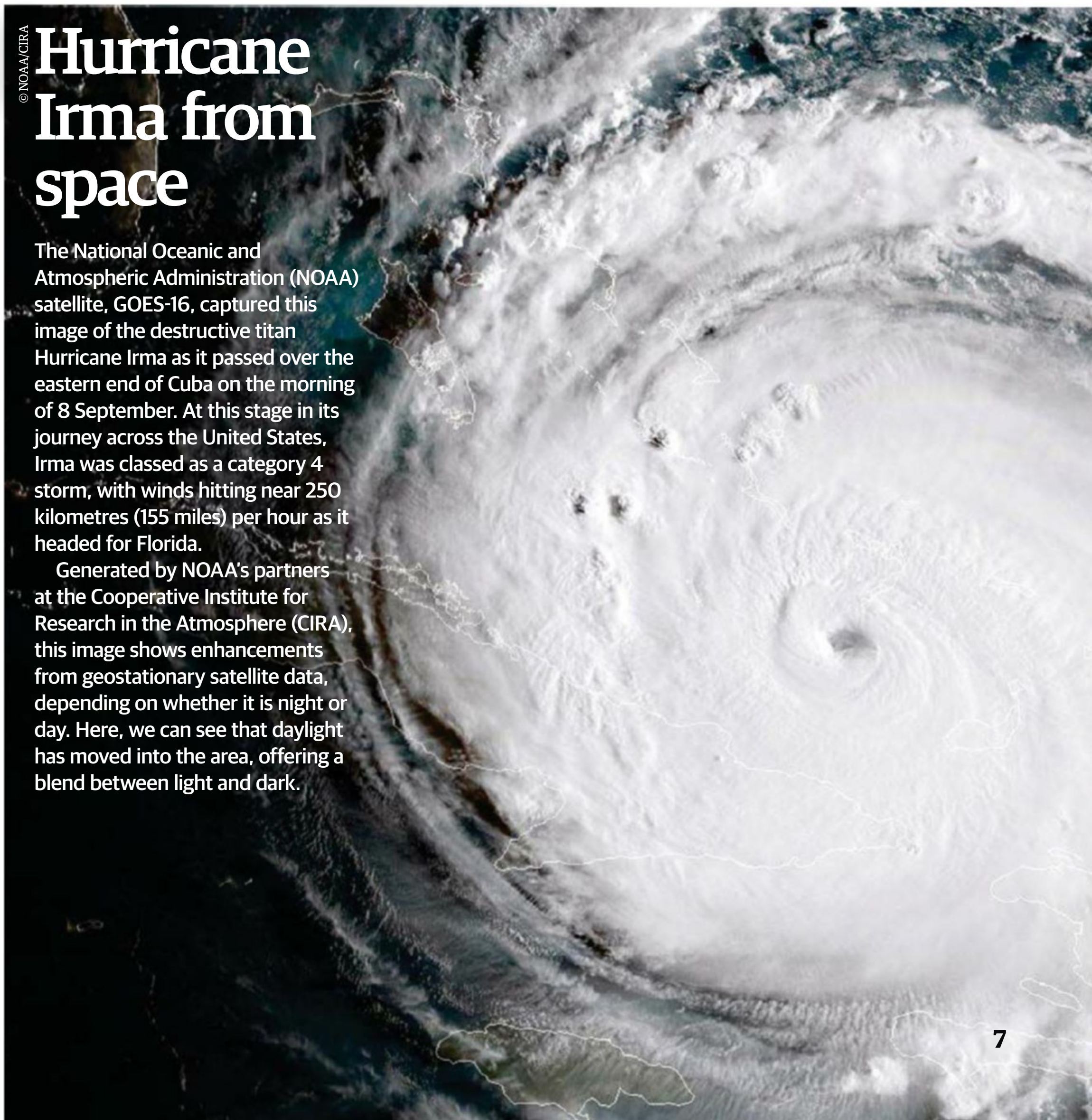

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Hurricane Irma from space

The National Oceanic and Atmospheric Administration (NOAA) satellite, GOES-16, captured this image of the destructive titan Hurricane Irma as it passed over the eastern end of Cuba on the morning of 8 September. At this stage in its journey across the United States, Irma was classed as a category 4 storm, with winds hitting near 250 kilometres (155 miles) per hour as it headed for Florida.

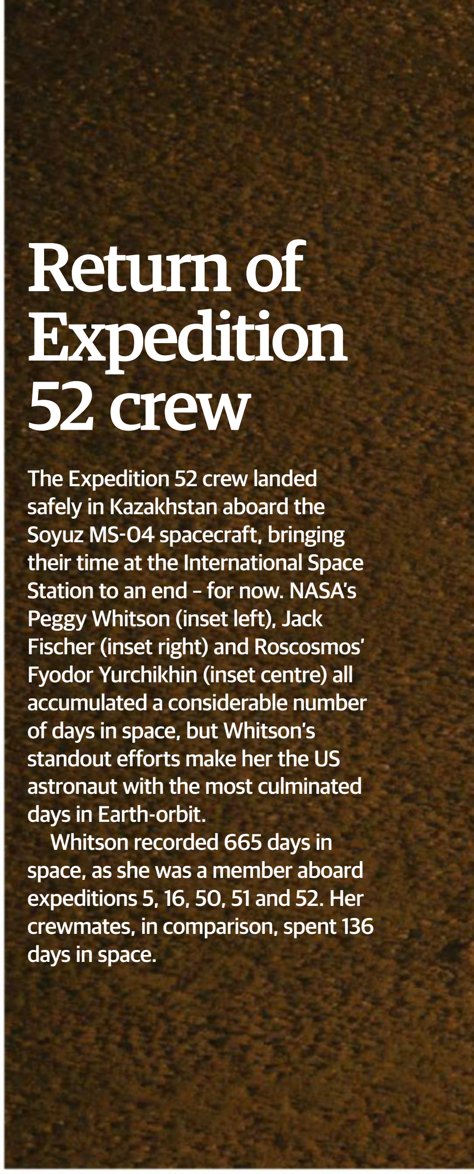
Generated by NOAA's partners at the Cooperative Institute for Research in the Atmosphere (CIRA), this image shows enhancements from geostationary satellite data, depending on whether it is night or day. Here, we can see that daylight has moved into the area, offering a blend between light and dark.

© NASA/GSFC/Solar Dynamics Observatory

The Sun throws a flare

The Sun is powerful and unpredictable. For years it can go relatively quiet about its business and then, without warning, arresting solar flares can erupt.

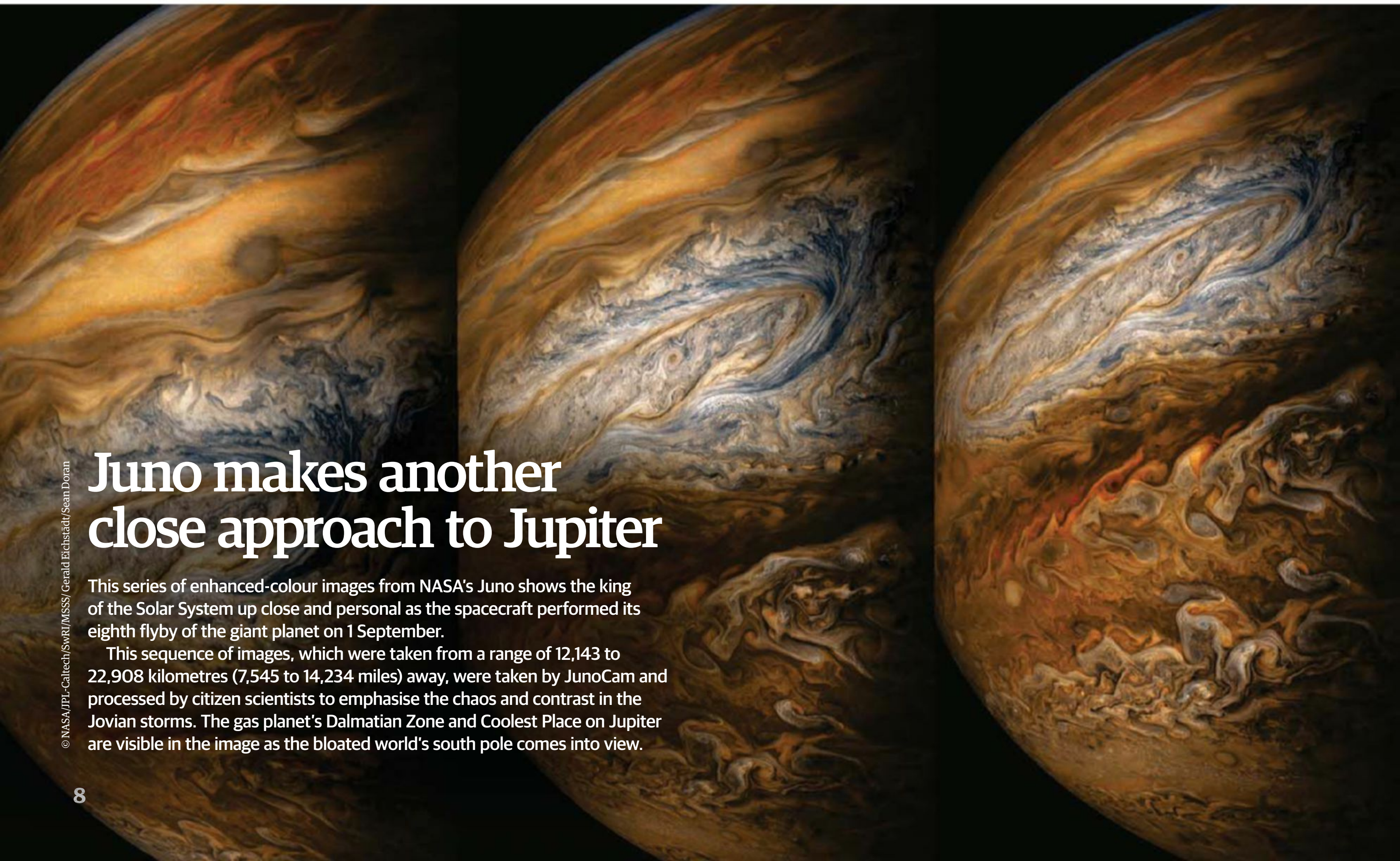
This is exactly what happened on the 6 September, as NASA's Solar Dynamics Observatory (SDO) observed an insanely intense X9.3 solar flare and Coronal Mass Ejection. The X-class of a flare is similar to how we categorise earthquakes with the Richter scale, and with a ranking of X9.3, this is the most intense solar flare recorded since December 2008.



Return of Expedition 52 crew

The Expedition 52 crew landed safely in Kazakhstan aboard the Soyuz MS-04 spacecraft, bringing their time at the International Space Station to an end – for now. NASA's Peggy Whitson (inset left), Jack Fischer (inset right) and Roscosmos' Fyodor Yurchikhin (inset centre) all accumulated a considerable number of days in space, but Whitson's standout efforts make her the US astronaut with the most culminated days in Earth-orbit.

Whitson recorded 665 days in space, as she was a member aboard expeditions 5, 16, 50, 51 and 52. Her crewmates, in comparison, spent 136 days in space.



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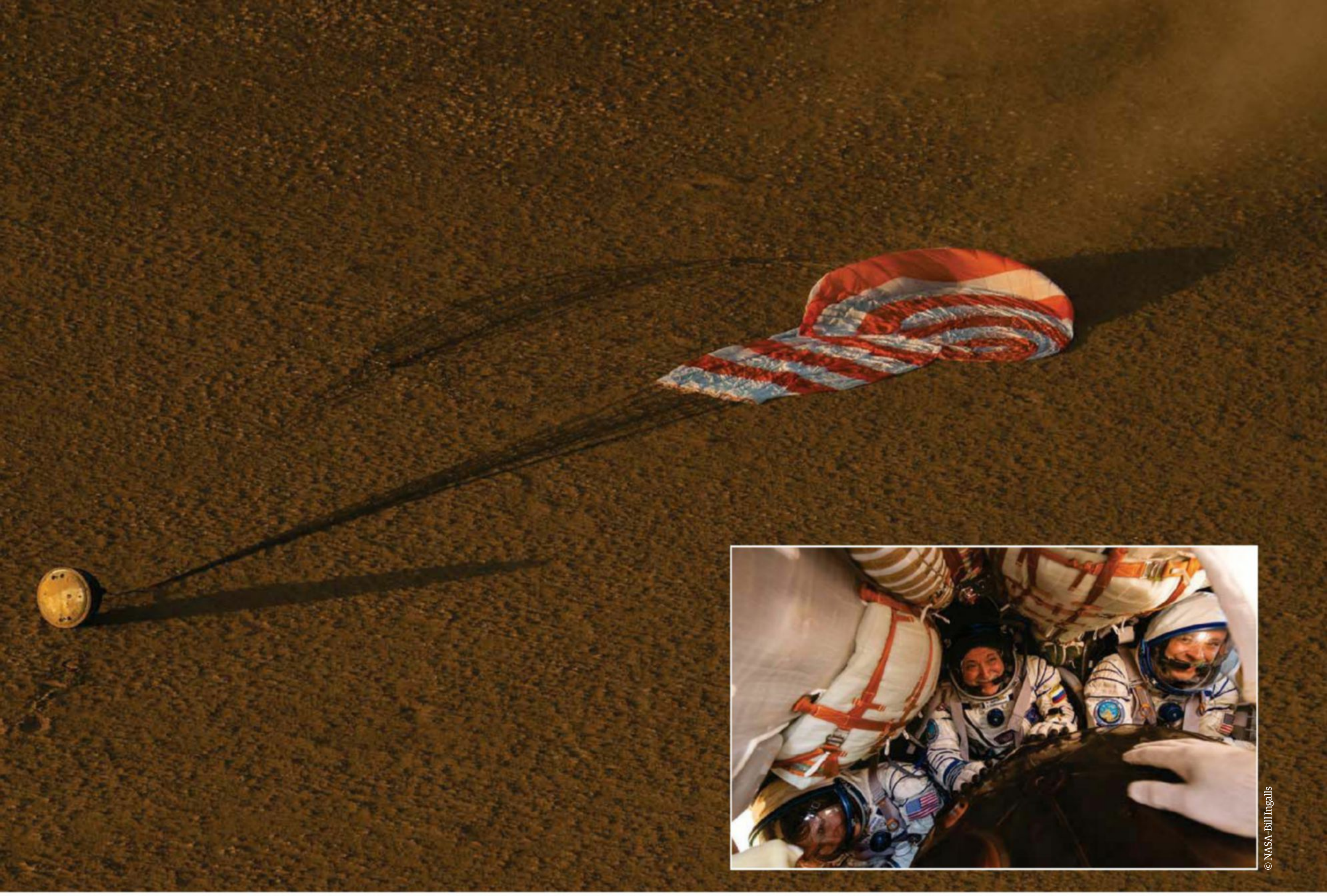
Juno makes another close approach to Jupiter

This series of enhanced-colour images from NASA's Juno shows the king of the Solar System up close and personal as the spacecraft performed its eighth flyby of the giant planet on 1 September.

This sequence of images, which were taken from a range of 12,143 to 22,908 kilometres (7,545 to 14,234 miles) away, were taken by JunoCam and processed by citizen scientists to emphasise the chaos and contrast in the Jovian storms. The gas planet's Dalmatian Zone and Coolest Place on Jupiter are visible in the image as the bloated world's south pole comes into view.



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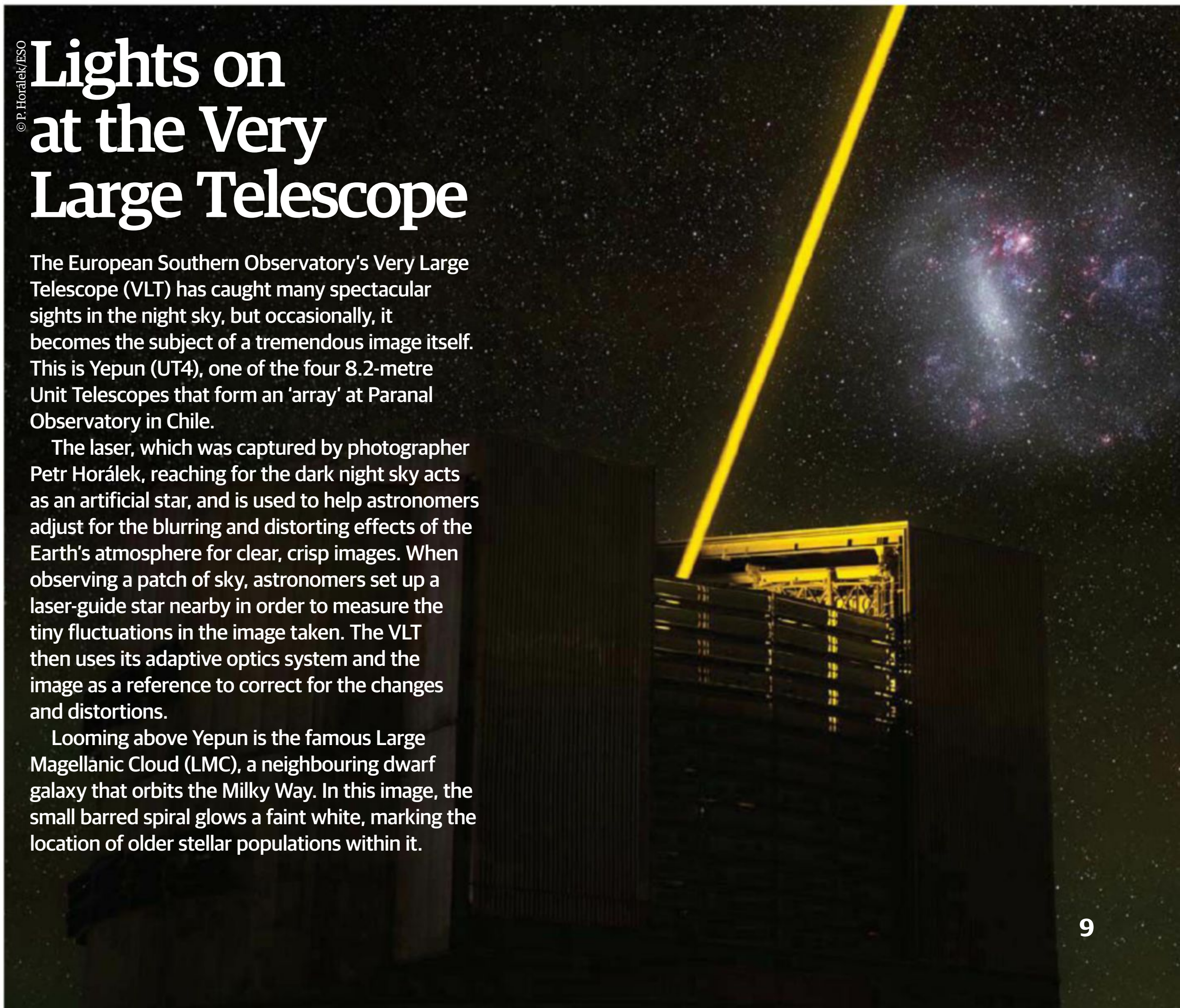


© P. Horálek/ESO

Lights on at the Very Large Telescope

The European Southern Observatory's Very Large Telescope (VLT) has caught many spectacular sights in the night sky, but occasionally, it becomes the subject of a tremendous image itself. This is Yepun (UT4), one of the four 8.2-metre Unit Telescopes that form an 'array' at Paranal Observatory in Chile.

The laser, which was captured by photographer Petr Horálek, reaching for the dark night sky acts as an artificial star, and is used to help astronomers adjust for the blurring and distorting effects of the Earth's atmosphere for clear, crisp images. When observing a patch of sky, astronomers set up a laser-guide star nearby in order to measure the tiny fluctuations in the image taken. The VLT then uses its adaptive optics system and the image as a reference to correct for the changes and distortions.

Looming above Yepun is the famous Large Magellanic Cloud (LMC), a neighbouring dwarf galaxy that orbits the Milky Way. In this image, the small barred spiral glows a faint white, marking the location of older stellar populations within it.

Space macaroons!

European Space Agency astronaut Thomas Pesquet plays with an arrival of a French delicacy on the International Space Station – macaroons. The treat, which was brought up to the Space Station by the Dragon spacecraft, was launched to celebrate Pesquet's birthday in February.

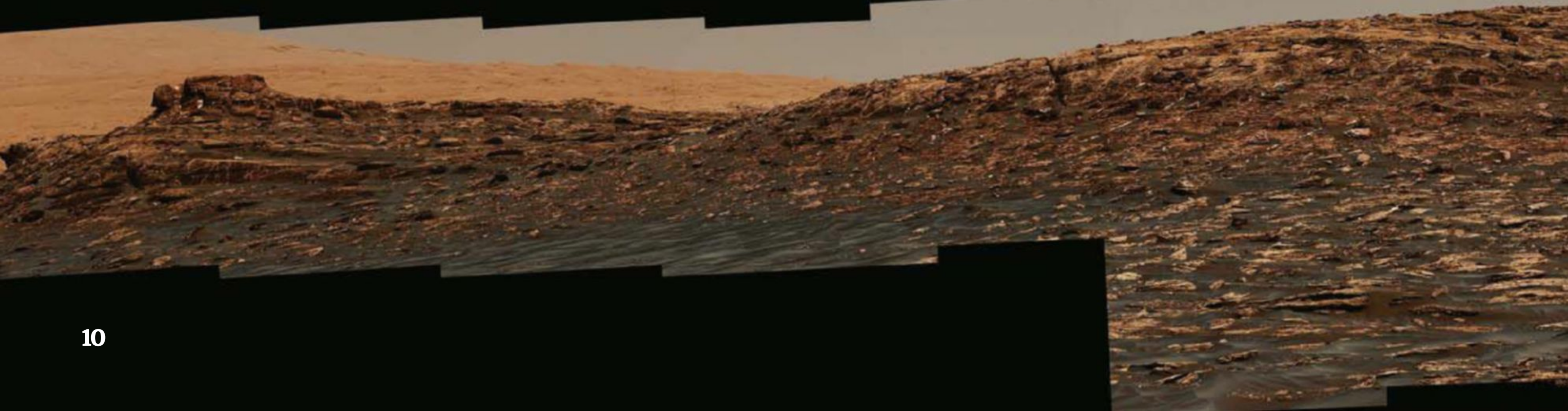
Astronauts must ensure an optimal diet, paired with constant exercise, in order to counteract the effects of spaceflight on the human body. Gaining weight in space is unusual for astronauts, with flight surgeons continually consulting those on board when building their menus - this ensures that they are fuelling themselves with a balanced diet.

© ESA/NASA

Curiosity snaps Vera Rubin Ridge

Named after the discoverer of dark matter, astrophysicist Vera Rubin, this ridge – previously known as the 'Hematite Ridge' – is depicted here in this panoramic shot captured by NASA's Curiosity rover, which has been trundling along the surface of the Red Planet since 2012. The scene combines 23 images taken with the Matcam's right-eye, telephoto-lens camera during the 1,734th Martian day of the rover's work on Mars.

The robotic view has been white-balanced so that the colours of the rock materials resemble how they would appear under the daytime-lighting conditions of Earth.



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Expedition 53 heads for the ISS

A Soyuz MS-06 spacecraft launches for the International Space Station (ISS), carrying with it Expedition 53 crewmembers from the Baikonur Cosmodrome in Kazakhstan. The astronauts (inset) on the expedition are Joe Acaba of NASA, Alexander Misurkin of Roscosmos and Mark Vande Hei, also of NASA.

Acaba, Misurkin and Vande Hei will spend approximately five-and-a-half months on the Earth-orbiting outpost, where they will continue to work on hundreds of experiments in biology, biotechnology, physics and Earth science.

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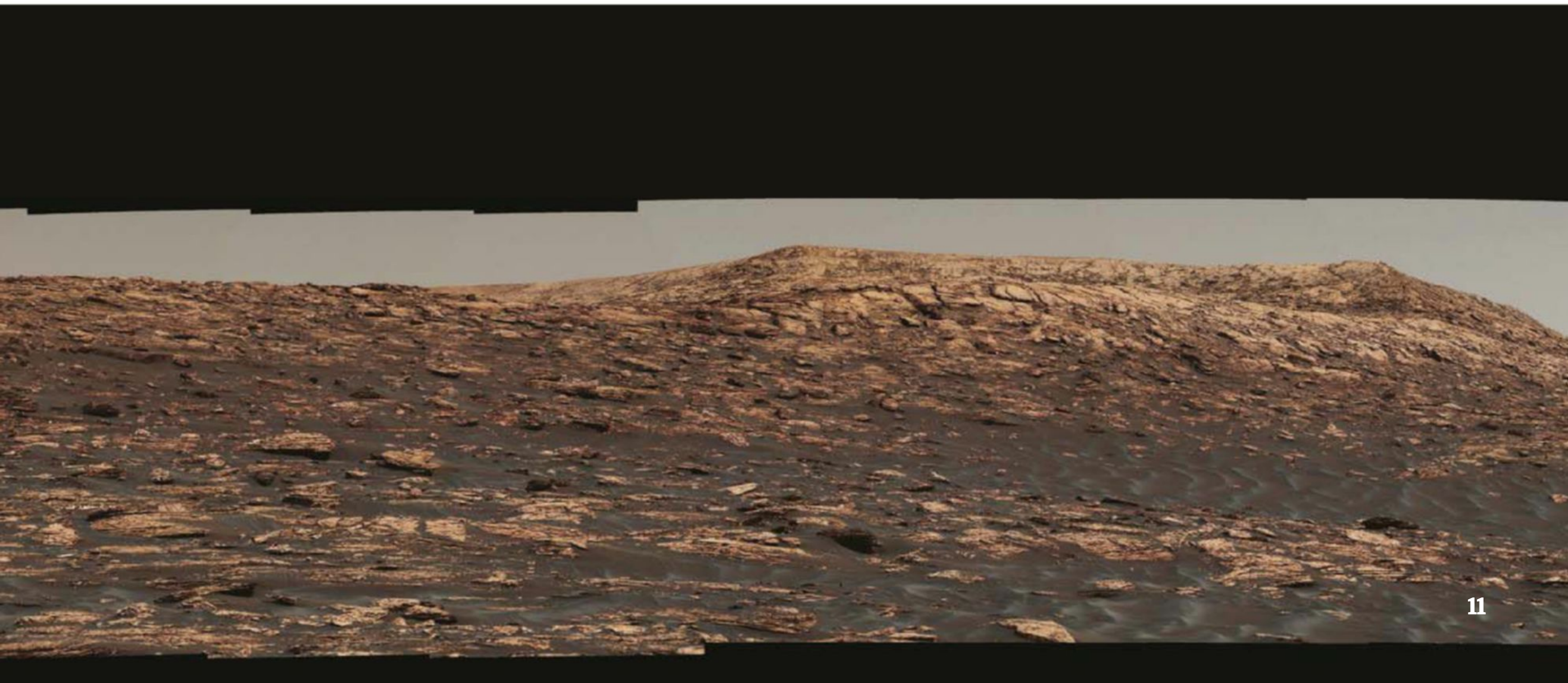


LAUNCH PAD

YOUR FIRST CONTACT WITH THE UNIVERSE

Planet Nine formed around the Sun, wasn't captured from space

New research suggests that the suspected ice world at the edge of our Solar System was also made around our nearest star

Astronomers exploring the origin of a potential extra planet orbiting the Sun far beyond Pluto claim it may well have formed more closely to home than originally thought. A team at the University of Sheffield say the hypothetical Planet Nine - which is believed to have a mass around ten-times that of Earth - is most likely to have formed around the Sun. If true, it flies in the face of previous claims that it had emerged within another planetary system and that it had been captured early in the history of the Solar System.

Firmer evidence for Planet Nine had emerged in January 2016 when astronomers Mike Brown and Konstantin Batygin from the California Institute of Technology studied the way far-flung objects in the Kuiper Belt were seen to move. But while there has been no direct observation of the planet, it has nevertheless led to speculation over how it formed and got into position.

A team led by Dr Richard Parker from Sheffield's Department of Physics and Astronomy now says it is unlikely the planet was captured when the Sun was still in its birth cluster. By ruling out such a scenario, Dr Parker and his team are suggesting the planet is more likely to have moved to the edge of the Solar System from the inner regions.

Indeed, by using a computer simulation of a theoretical cluster of stars - and by making it easy for a star to capture a planet - they found just five to ten in every 10,000 planets were captured on to an orbit like Planet Nine's, making their alternative theory more plausible.

"We know that planetary systems form at the same time as stars, and when stars are very young they are usually found in groups where interactions between stellar siblings are common," explains Dr Parker. "Therefore, the environment where stars form directly affects planetary systems like our own, and is usually so densely populated that stars can capture other stars or planets. "In this work, we have shown that - although capture is common - ensnaring planets onto the postulated orbit of Planet Nine is very improbable. We're not ruling out the idea of Planet Nine, but instead we're saying that it must have formed around the Sun, rather than captured from another planetary system."

The existence of Planet Nine was first suggested in 2014 by astronomers Chad Trujillo and Scott S. Sheppard, and it is said to take between 10,000 and 20,000 years to complete an orbit of the Sun.

> "Ensnaring planets onto the postulated orbit of Planet Nine is very improbable"

Astronomers uncover first mid-sized black hole in the galaxy

There is strong evidence of a mid-sized black hole 100,000-times larger than the Sun, which hints at a cosmic missing link

©NRAO/AUI/NSF

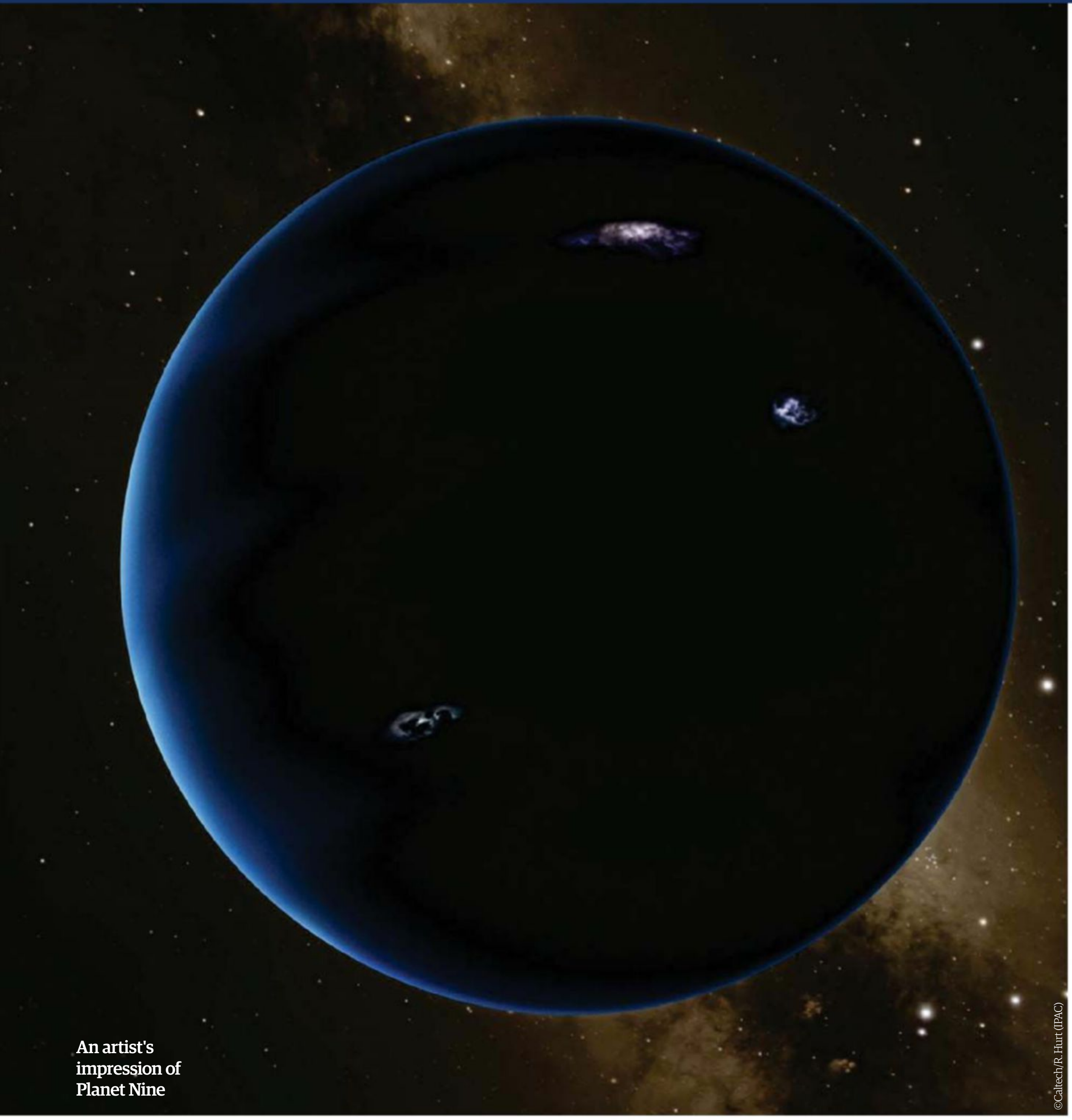
Another black hole has been discovered near the heart of the Milky Way, which, if confirmed, would make it the second largest in the galaxy. Weighing in at around 100,000-times the mass of the Sun, it lags way behind Sagittarius A*, but its finding is nevertheless of huge significance.

That's because such intermediate black holes have never been identified before, although their existence has long been believed. Scientists say its discovery by astronomers in Japan may help to explain the evolution of the Milky Way. One theory suggests that supermassive black holes such as Sagittarius A* actually form from the merging of intermediate black holes.

"It is possible intermediate-mass black holes - which are formed by the runaway coalescence of stars in young compact star clusters - merge at the centre of a galaxy to form a supermassive black hole," says Professor Tomoharu Oka, a researcher at Keio University and the lead astronomer of the study.

Such evidence was uncovered by pointing a telescope located in the Atacama desert in Chile towards a toxic gas cloud. The astronomers found that the gases were moving at different speeds, which indicated they were being pulled by immense gravitational forces.

Radio waves were observed at the centre of the cloud, while computer simulations allowed the scientists to point towards the existence of an intermediate black hole. "Based on the careful analysis of gas kinematics we concluded a compact object with a mass of about 100,000 solar masses is lurking in this cloud," Prof Oka adds.



An artist's impression of Planet Nine

©Caltech/R. Hurt (IPAC)

Nearby stars could send comets to Earth

Our planet could be showered by space snowballs in at least 1.3 million years

Stars that neighbour the Milky Way may get so close to the Sun in the distant future, that they could end up sending comets hurtling towards Earth. At least that's according to the European Space Agency (ESA), which has been looking at the likelihood of the stars straying into the Oort cloud – a collection of icy objects enveloping the Solar System far beyond the orbit of Neptune.

By monitoring the movements of some 300,000 stars surveyed by ESA's Gaia telescope, it has been found that 16 stars are likely to come within 37 trillion miles of the Sun. At such a distance, the likelihood of their gravitational force dislodging comets at the far end of the Solar System is greatly increased. This could send a comet into the inner Solar System and put it on a collision course with Earth or other planets.

Such a thing is only likely to happen in about 5 million years, although one star, called Gliese 710, could have a close encounter in just 1.3 million years time, when it passes within 1.6 trillion miles of our nearest star. Such predications of stellar movements show the power of Gaia. It catalogued a billion stars in its first 14 months, allowing astronomers to determine the paths of hundreds of thousands of stars over millions of years.

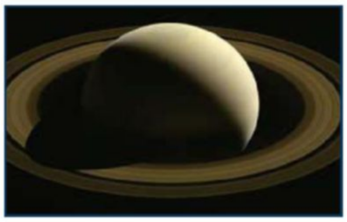
Stars that neighbour the Solar System could send comets towards the Earth

©NASA/JPL-Caltech

Space News in Brief

Cosmic dust in Dover's cliffs

The White Cliffs of Dover contain the fossilised remains of cosmic dust. Dr Martin Suttle, lead scientist from Imperial College London's Department of Earth Science and Engineering, says the dust particles could provide new information about the early Solar System.



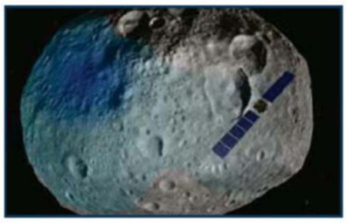
©NASA/JPL/Space Science Institute

NASA eyes return to Saturn

Now that NASA's Cassini spacecraft had ended its mission – plunging into the planet – its project manager Earl Maize is already pushing for a return. "We've got to go back," he tells **All About Space**. "We know it." Five Saturn-based concepts are already being prepared.

Hot alien world swallows light

A study into the hot exoplanet WASP-12b has shown it to be pitch black. According to Taylor Bell, from McGill University in Montreal, it has a tiny reflectance of 0.064, which pales in comparison to the Earth's 0.37. The exoplanet is about 1,400 light years from our planet.



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Asteroid Vesta may contain ice

Ice could be buried beneath the surface of the Solar System's second largest asteroid, Vesta, according to a study. Planetary scientists at the University of Southern California in Los Angeles suggest its cratered surface is due to the melting of ice beneath, smoothing certain areas.

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Rare chemical find boosts chance of past Martian life

Boron has been detected on Mars, suggesting life forms really could have existed on the Red Planet

NASA's Curiosity rover has found boron during its exploration of the Gale Crater on Mars - pointing to further evidence that life once existed on the Red Planet. Data collected by the laser-shooting ChemCam as the robot climbs a layered mountain during its exploration of the Gale Crater, suggests possible past microbial life. While it isn't definitive proof, it is certainly getting scientists excited.

This is down to RNA (ribonucleic acid), which is a nucleic acid present in all modern life. "Because borates may play an important role in making RNA - one of the building blocks of life - finding boron on Mars further opens the possibility that life could have once arisen on the planet," explains Patrick Gasda, a postdoctoral researcher at Los Alamos National Laboratory and lead researcher of the study. He says borates are one possible bridge from simple organic molecules to RNA. "Without RNA, you have no life," Dr Gasda adds. "The presence of boron tells us that, if organics were present on Mars, these chemical reactions could have occurred."

The latest breakthrough backs a previous finding of boron in 2013, which had been discovered within a Martian meteor that had landed in Antarctica. This time the boron was located in calcium-sulphate mineral veins in the bedrock in Gale Crater, meaning it was present in groundwater on the planet.

It is the first time boron has been found on Mars itself, and it shows the borates were present in water of between zero and 60 degrees Celsius (32 to 140 degrees Fahrenheit) and with neutral-to-alkaline pH.

The Curiosity rover has made a huge breakthrough with regards to the potential of life on Mars

© NASA

Titanium found in inferno world's atmosphere

Rare material detected in the skies of a scorching hot exoplanet

An inferno planet that suffers temperatures in excess of 2,000 degrees Celsius (3632 degrees Fahrenheit) has been found to have small amounts of titanium oxide in its atmosphere. Not only does this mark the first time the material has been detected in the skies of any planet, it highlights just how hot WASP-19b actually is. After all, titanium oxide is usually found in the atmospheres of cool stars.

WASP-19b, which is 815 light years away from Earth, is so close to its parent star that it is able to complete its orbit in 19 hours. Its size has earned it the label of a Hot Jupiter, and scientists say the presence of titanium oxide suggests that heat is prevented from entering or escaping the planet. This results in a higher temperature within the upper atmosphere and a lower one further down, here's certainly no chance of life.

The findings were made by astronomers using ESO's Very Large Telescope. Led by Elyar Sedaghati, an ESO fellow and recent graduate of TU Berlin, the scientists made use of the FORS2 instrument, which provides data on an atmosphere's chemical composition, temperature and pressure structure. Aside from titanium oxide was water and traces of sodium, but it's the former that is proving to be most exciting.

"The presence of titanium oxide in the atmosphere of WASP-19b can have substantial effects on the atmospheric temperature structure and circulation," says Ryan MacDonald, an astronomer at the University of Cambridge. The observations were collected for over more than a year.

An ultra-thin 'blanket' may rid space of debris

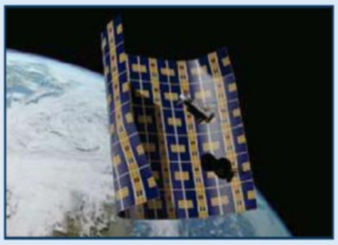
With more than 500,000 pieces of junk circling the Earth, space is proving to be rather cluttered and dangerous. However, a new ultra-thin spacecraft could prove to be the answer - assuming it gets off the ground, that is.

Aerospace Corporation's Brane Craft looks like a blanket, and it hopes to sweep through space and collect debris. By sending it back through the atmosphere, the junk should burn, thereby cleaning space of even the smallest of particles.

The spacecraft is being refined after receiving a second round of funding from the NASA Innovative Advanced Concepts program, but there is still much to do.

Brane has to be bullet proof to prevent junk penetrating it, yet the structure is just half the width of a human hair. It's also vulnerable to damaging radiation, but by building it in segments it should be able to withstand disruption to certain cells and continue working.

Space junk moves so fast that it can destroy satellites and injure astronauts, so removal is important.



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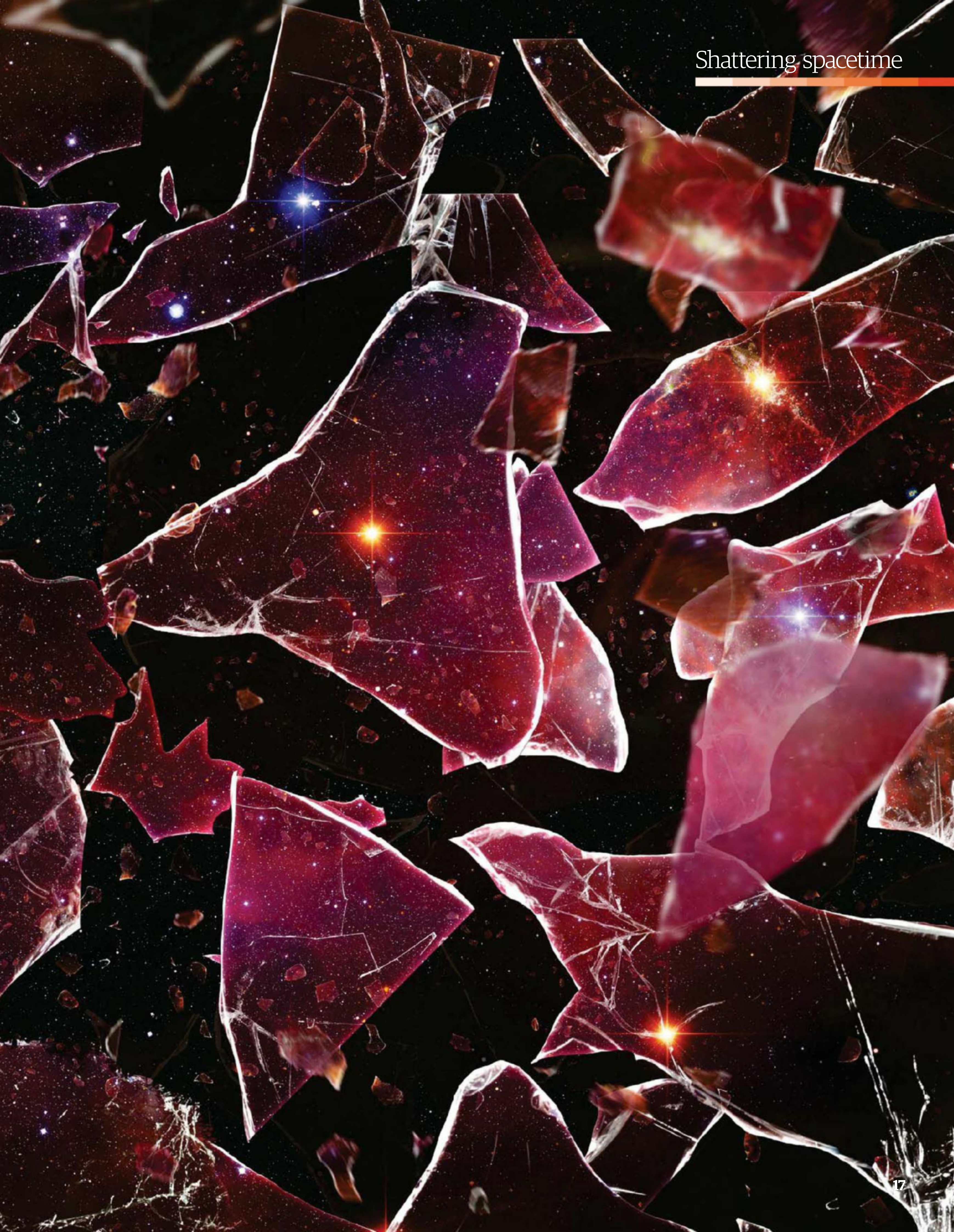
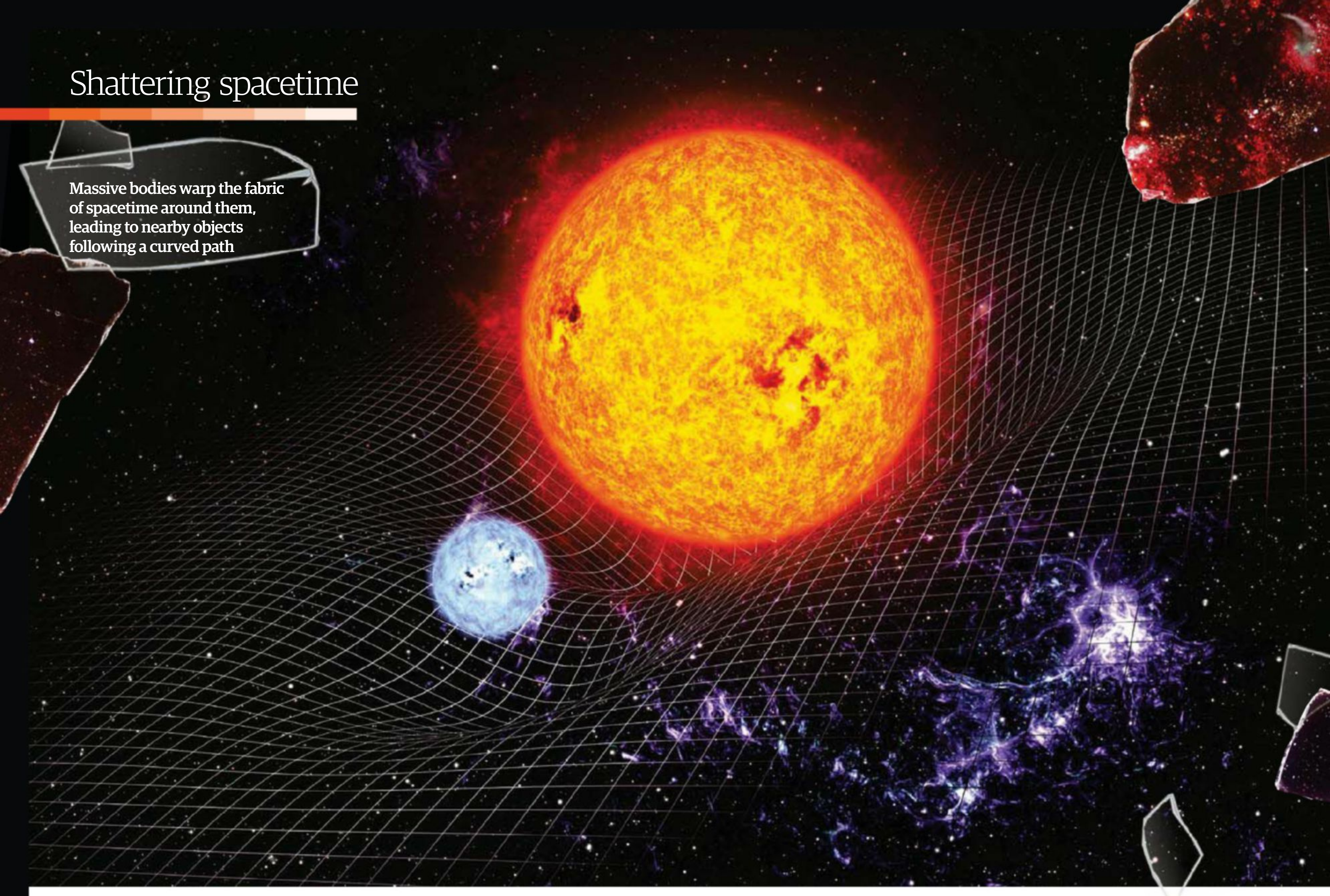
WAS EINSTEIN WRONG?

SHATTERING SPACETIME

To better understand the universe we may need to kill off Einstein's idea of space and time

Written by Colin Stuart

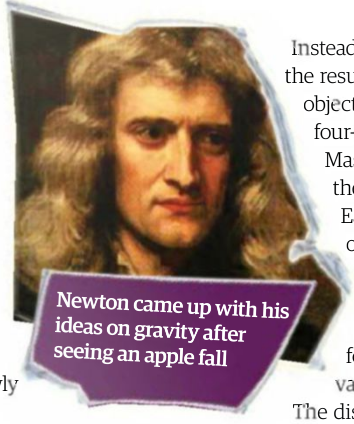




Massive bodies warp the fabric of spacetime around them, leading to nearby objects following a curved path

As in history, revolutions are the life blood of science. Bubbling undercurrents of disquiet boil over until a new regime emerges to seize power. Then everyone's attention turns to toppling their new ruler. The king is dead, long live the king.

This has happened many times in the history of physics and astronomy. First, we thought the Earth was at the centre of the solar system – an idea that stood for over a thousand years. Then Copernicus stuck his neck out to say that the whole system would be a lot simpler if we are just another planet orbiting the Sun. Despite much initial opposition, the old geocentric picture eventually buckled under the weight of evidence from the newly invented telescope.



Newton came up with his ideas on gravity after seeing an apple fall

Then Newton came along to explain that gravity is why the planets orbit the Sun. He said all objects with mass have a gravitational attraction towards each other. According to his ideas we orbit the Sun because it is pulling on us, the Moon orbits the Earth because we are pulling on it. Newton ruled for two-and-a-half centuries before Albert Einstein turned up in 1915 to usurp him with his General Theory of Relativity. This new picture neatly explained inconsistencies in Mercury's orbit, and was famously confirmed by observations of a solar eclipse off the coast of Africa in 1919.

> "If we understand the quantum structure of spacetime better that will have an impact on future technologies" **Sabine Hossenfelder**

Instead of a pull, Einstein saw gravity as the result of curved space. He said that all objects in the universe sit in a smooth, four-dimensional fabric called spacetime. Massive objects such as the Sun warp the spacetime around them and so Earth's orbit is simply the result of our planet following this curvature. To us that looks like a Newtonian gravitational pull. This spacetime picture has now been on the throne for over 100 years and has so far vanquished all pretenders to its crown.

The discovery of gravitational waves in 2015 was a decisive victory, but, like its predecessors, it too might be about to fall. That's because it is fundamentally incompatible with the other big beast in the physics zoo: quantum theory.

The quantum world is notoriously weird. Single particles can be in two places at once, for example. Only by making an observation do we force it to 'choose'. Before an observation we can only assign probabilities to the likely outcomes. In the 1930s, Erwin Schrödinger devised a famous way to expose how perverse this idea is. He imagined a cat in a sealed box accompanied by a vial of poison attached to a hammer. The hammer is hooked up to a device that measures the quantum state of a particle. Whether or not the hammer smashes the vial and kills the cat hinges on that measurement, but quantum physics says that until such a measurement is made the particle is simultaneously in both states, which means the vial is both broken and unbroken and the cat is alive and dead.

Such a picture cannot be reconciled with a smooth, continuous fabric of spacetime. "A gravitational field cannot be in two places at once," says Sabine Hossenfelder, a theoretical physicist at the Frankfurt Institute for Advanced Studies. According to Einstein, spacetime is warped by matter and energy, but quantum physics says matter and energy exist in multiple states simultaneously – they can be both here and over there. "So where is the gravitational field?" asks Hossenfelder. "Nobody has an answer to that question. It's kind of embarrassing," she says.

Try and use general relativity and quantum theory together and it doesn't work. "Above a certain energy you get probabilities that are larger than one," says Hossenfelder. One is the highest probability possible – it means an outcome is certain. You can't be more certain than certain. Equally, calculations sometimes give you the answer infinity, which has no real physical meaning. The two theories are therefore mathematically inconsistent. So, like many monarchs throughout history, physicists are seeking a marriage between rival factions to secure peace. They're searching for a theory of quantum gravity – the ultimate diplomatic exercise in getting these two rivals to share the throne. This has seen theorists turn to some outlandish possibilities.

Arguably the most famous is string theory. It's the idea that sub-atomic particles such as electrons and quarks are made from tiny vibrating strings. Just as you can play strings on a musical instrument to create different notes, string theorists argue that different combinations of strings create different particles. The attraction of the theory is that it can reconcile general relativity and quantum physics, at least on paper. However, to pull that particular rabbit out of the hat, the strings have to vibrate across eleven dimensions – seven more than the four in Einstein's spacetime fabric. As yet there is no experimental evidence that these extra dimensions

Albert Einstein dispensed with the Newtonian picture of gravity as a force, replacing it with spacetime

One way to reconcile general relativity and quantum theory says reality is made of vibrating strings

Why can't Einstein and quantum mechanics get along?

Quantum mechanics

Particles are waves and waves are particles

This wave-particle duality is central to quantum physics. Light, for example, can be thought of as being made of particles called photons, or as a propagating electromagnetic wave.

All properties are 'quantised'

Values in quantum physics are a bit like shoes – they only come in set sizes. Physicists call these 'quanta'. An electron, for example, can only orbit the atomic nucleus in a limited number of configurations.

Objects exist in many states at once

Physicists say electrons exist in a 'superposition' of states. It's not in a definite state until we measure it, and beforehand we can only assign probabilities to the likely outcome.

Non-locality: spooky action at distance

Take a pair of entangled particles, change the properties of one and the other will change instantly. Einstein called this 'spooky action at distance' and was deeply disturbed by it.

Why they don't agree

Gravitational fields aren't in a superposition

According to Einstein, a gravitational field cannot be here **and** there, yet, according to quantum theory, the matter and energy that warp spacetime to create it can. Something has to give.

Gravity doesn't have a boson

There are four fundamental forces: gravity, electromagnetism, the strong and weaker nuclear forces. Quantum physics says the last three forces act between objects through the exchange of particles called bosons. No one has found a boson for gravity.

You get probabilities higher than one

Probabilities run from zero for impossible to one for certain. Combining quantum physics and relativity at high energies gives probabilities higher than one. You can't be more certain than certain.

You often get the answer 'infinity'

Other calculations give the answer infinity when you try and calculate physical quantities. Infinity is a glaring neon signpost saying you've got the physics wrong. You cannot have an infinite amount of energy, for example.

General relativity

The speed of light is sacrosanct

Nothing can travel through space faster than the speed of light, yet entangled particles appear to defy this rule. As of yet there is no agreed explanation for this.

Space and time are really spacetime

The three dimensions of space and one of time that we experience are really wrapped up together in a four-dimensional fabric called spacetime. This fabric is smooth and continuous.

Gravity is geometry

Newton was wrong – gravity isn't a pull from a massive object. Instead, it is the effect we see of bodies following a curved path through spacetime as the result of a massive object warping it.

Acceleration and gravity are equivalent

The equivalence principle says that you cannot distinguish between a gravitational pull and an acceleration. Accelerate through space at 9.8m/s^2 and you'll experience that same 'gravity' as on Earth.

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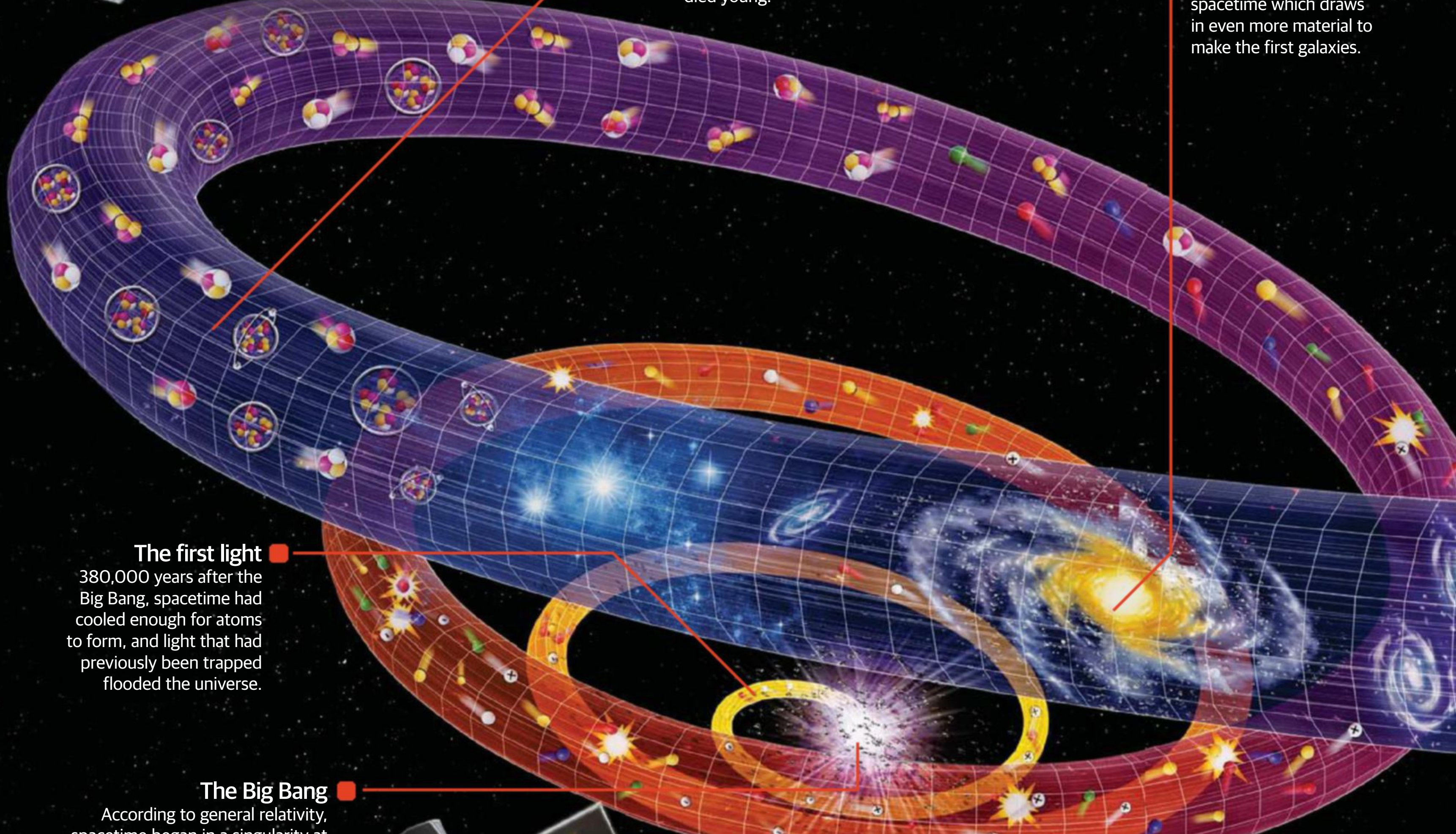
What do we know about spacetime?



The first stars
After 100 to 200 million years, slightly denser regions of spacetime collapsed to form the first stars. Incredibly massive, they lived fast and died young.

The first galaxies
A billion years after the Big Bang, stars cluster into dense regions of spacetime which draws in even more material to make the first galaxies.

The first light
380,000 years after the Big Bang, spacetime had cooled enough for atoms to form, and light that had previously been trapped flooded the universe.

The Big Bang
According to general relativity, spacetime began in a singularity at the Big Bang 13.8 billion years ago. It has been expanding ever since.

History of theories of spacetime

100 CE The Ptolemaic model
Claudius Ptolemy creates a model with the Earth at the centre of creation with the Sun, Moon and planets orbiting around us. There's no explanation of why they behave that way.

1543 Copernicus publishes his heliocentric model
Polish mathematician Nicolaus Copernicus argues that the Sun is in the centre of the solar system. His book *De revolutionibus orbium coelestium* is one of the most important scientific texts of all time.

1687 Newton's book *Principia* is published
In his landmark work Newton sets out his law of universal gravitation. All masses attract all other masses in space with a force related to the distance between them.

1803 John Dalton proposes indivisible atoms
The English chemist says that all matter is made up of tiny, unbreakable and indestructible building blocks called atoms. He was able to successfully explain a lot of chemistry using this idea.

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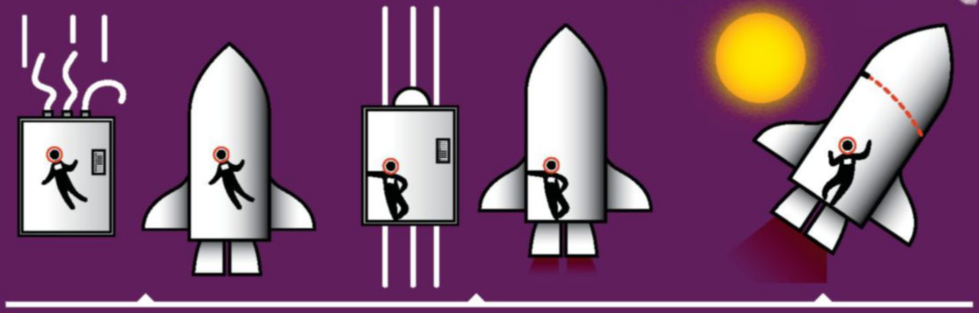
General relativity explained



Freefall and floating

Einstein realised that freefalling because of gravity is the same as floating with no gravity. He concluded that gravity cannot be a force as Newton had said.

Gravity and acceleration

Accelerating in a vehicle pushes you into your seat. Gravity and acceleration feel the same, so they have the same cause: a curved path through spacetime.

The bending of light

Light from a torch would appear to bend as you accelerate. Acceleration is the same as curved spacetime, so light should also be bent by it.

really exist. “It might be interesting mathematics, but whether it describes the spacetime in which we live, we don't really know until there is an experiment,” says Jorma Louko from the University of Nottingham.

Partly inspired by string theory's perceived failings, other physicists have turned to an alternative called Loop Quantum Gravity (LQG). They can get the two theories to play nicely if they do away with one of the central tenets of general relativity: that spacetime is a smooth, continuous fabric. Instead, they argue, spacetime is made up of a series of interwoven loops - that it has structure at the smallest size scales. This is a bit like a length of cloth. At first glance it looks like one smooth fabric. Look closely, however, and you'll see it is really made of a network of stitches. Alternatively, think of it like a photograph on a computer screen: zoom in and you'll see it is really made of individual pixels.

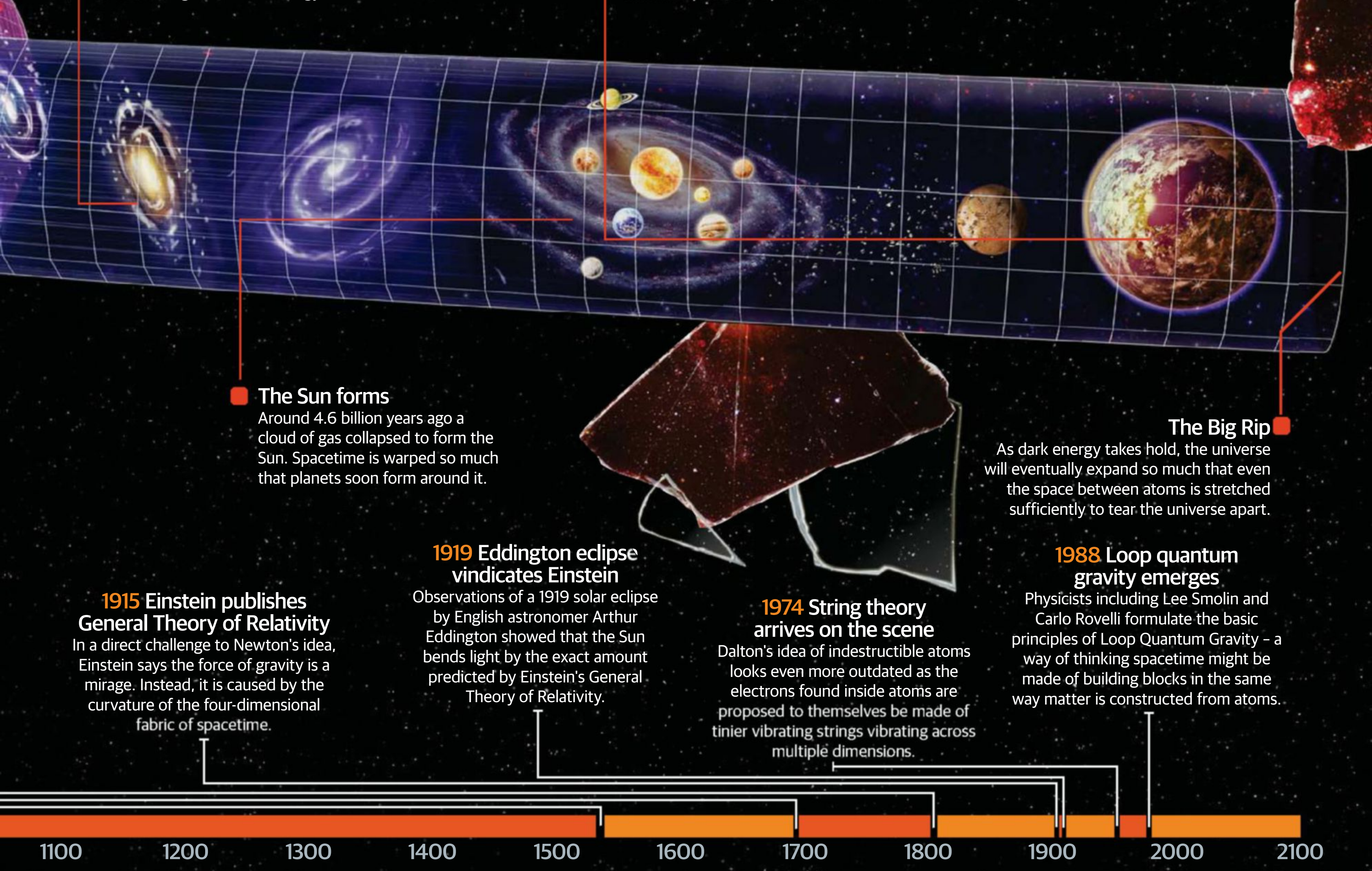
The trouble is that when LQG physicists say small they mean really small. These defects in spacetime would only be apparent on the level of the Planck scale - around a trillionth of a trillionth of a trillionth of a metre. That's so tiny that there would be more loops in a cubic centimetre of space than cubic centimetres in the entire observable universe. “If spacetime only differs on the Planck scale then this would be difficult to test in any particle accelerator,” says Louko. You'd need an atom smasher

The universe accelerates

Having gradually slowed since the Big Bang, spacetime begins to stretch at an accelerating pace due to something called dark energy.

The here and now

Today Earth is home to physicists who are pondering how best to combine quantum theory with Einstein's picture of spacetime.



The Sun forms

Around 4.6 billion years ago a cloud of gas collapsed to form the Sun. Spacetime is warped so much that planets soon form around it.

The Big Rip

As dark energy takes hold, the universe will eventually expand so much that even the space between atoms is stretched sufficiently to tear the universe apart.

1915 Einstein publishes General Theory of Relativity

In a direct challenge to Newton's idea, Einstein says the force of gravity is a mirage. Instead, it is caused by the curvature of the four-dimensional fabric of spacetime.

1919 Eddington eclipse vindicates Einstein

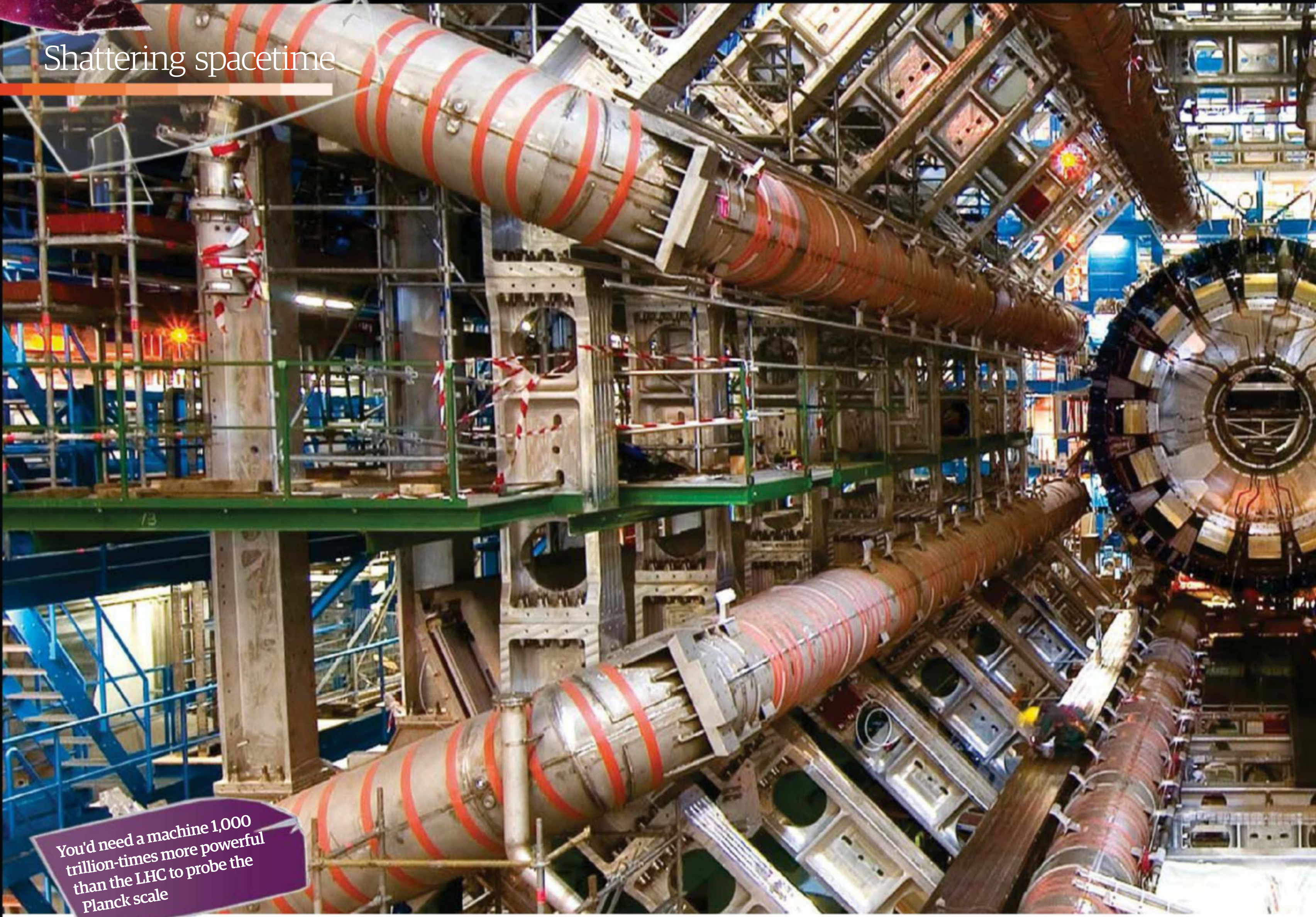
Observations of a 1919 solar eclipse by English astronomer Arthur Eddington showed that the Sun bends light by the exact amount predicted by Einstein's General Theory of Relativity.

1974 String theory arrives on the scene

Dalton's idea of indestructible atoms looks even more outdated as the electrons found inside atoms are proposed to themselves be made of tinier vibrating strings vibrating across multiple dimensions.

1988 Loop quantum gravity emerges

Physicists including Lee Smolin and Carlo Rovelli formulate the basic principles of Loop Quantum Gravity - a way of thinking spacetime might be made of building blocks in the same way matter is constructed from atoms.



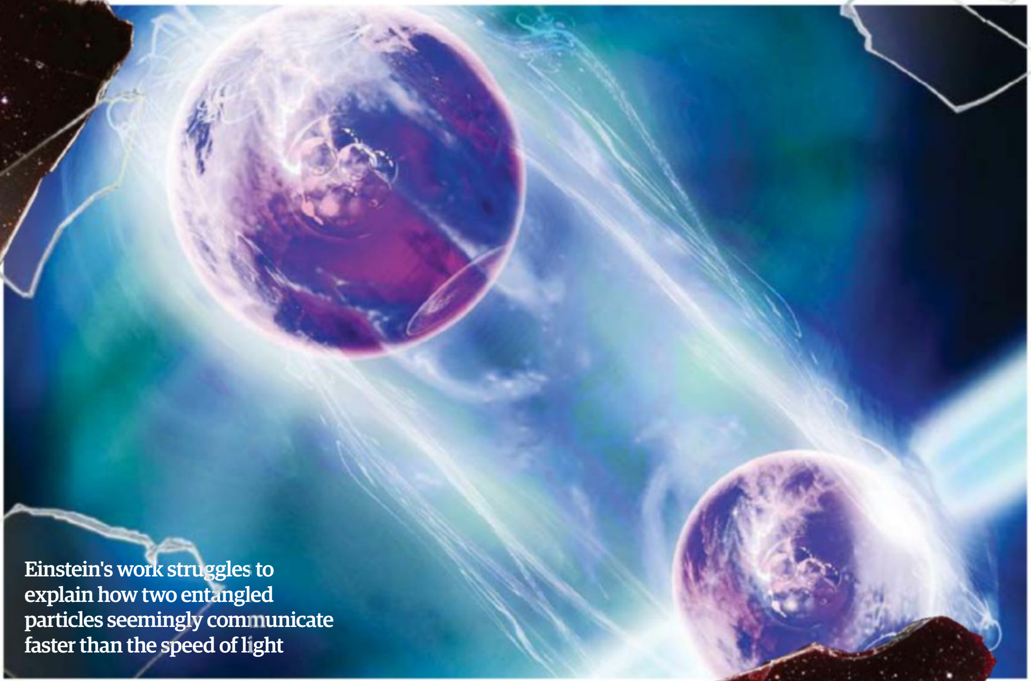
You'd need a machine 1,000 trillion-times more powerful than the LHC to probe the Planck scale

a 1,000-trillion-times more powerful than the Large Hadron Collider (LHC) at CERN. How, then, can you detect spacetime defects that small? The answer is to look across a large area of space.

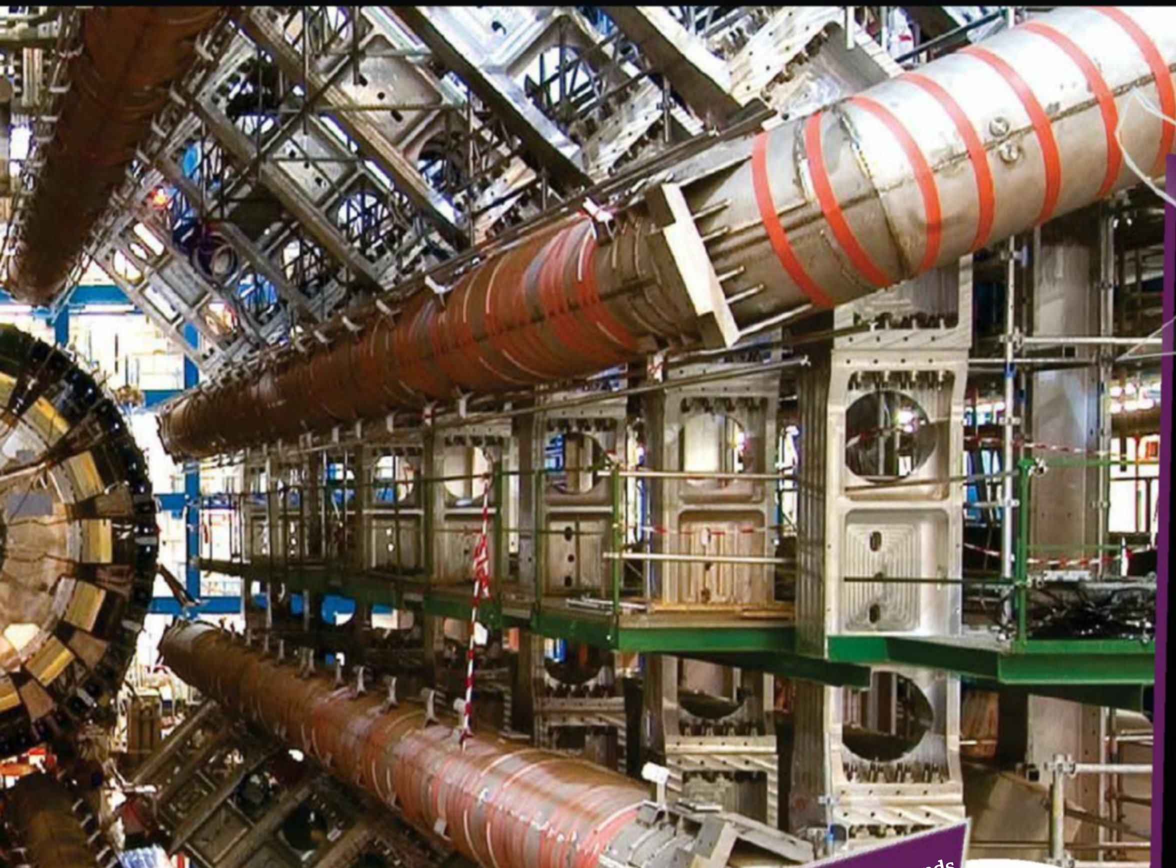
Light arriving here from the furthest reaches of the universe has travelled through billions of light years of spacetime along the way. While the effect of each spacetime defect would be tiny, over those distances interactions with multiple defects might well add up to a potentially observable effect. For the last decade astronomers have been using light from far-off Gamma Ray Bursts to look for evidence in support of LQG. These cosmic flashes are the result of massive stars collapsing at the ends of their lives, and there is something about these distant detonations we currently cannot explain. "Their spectrum has a systematic distortion to it," says Hossenfelder, but no one knows if that is something that happens on the way here or if it's something to do with the source of the bursts themselves. The jury is still out.

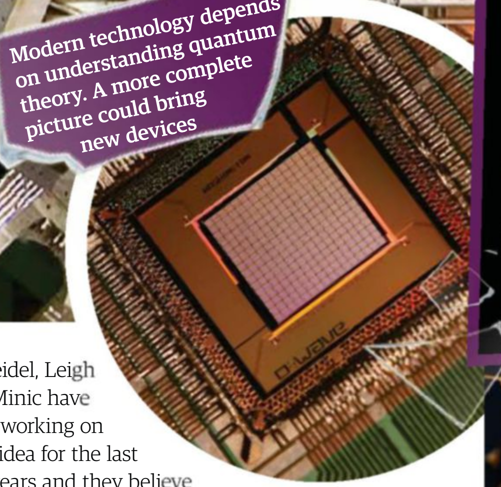
To make progress we might have to go a step further than saying spacetime isn't the smooth, continuous fabric Einstein suggested. According to Einstein, spacetime is like a stage that remains in place whether actors are treading its boards or not - even if there were no stars or planets dancing around, spacetime would still be there. However, physicists Laurent Freidel, Robert Leigh and Djordje Minic think that this picture is holding us back. They believe spacetime doesn't exist independently of the objects in it. Spacetime is defined by the way objects interact.

"Whether it describes the spacetime in which we live, we don't really know until there is an experiment" **Jorma Louko**



Einstein's work struggles to explain how two entangled particles seemingly communicate faster than the speed of light





Modern technology depends on understanding quantum theory. A more complete picture could bring new devices

Replacing spacetime

String theory
Fundamental particles such as electrons are made of tiny strings that vibrate across ten spatial dimensions (plus one time dimension). This picture can avoid infinities when combining quantum theory and general relativity, but it cannot currently be tested.

Loop Quantum Gravity
Spacetime is not a smooth fabric, but made up of a network of tiny stitches instead. This is potentially testable by looking at light reaching us from Gamma Ray Bursts (GRBs) in the distant universe.

Modular spacetime
Spacetime is only a stage when it has actors on it. In other words, interactions between objects create spacetime. This can potentially explain the quirks of non-locality and quantum entanglement.

Supergravity
This is the combination of general relativity with a popular, but unproven theory called supersymmetry – the same theory is the leading candidate to explain dark matter.

Causal set theory
Spacetime is not a continuous fabric but has a structure based on regions that have a link between past and future. It is based on work by David Malament and Rafael Sorkin.

That would make spacetime an artefact of the quantum world itself, not something to be combined with it. “It may sound kooky,” says Minic, “but it is a very precise way of approaching the problem.”

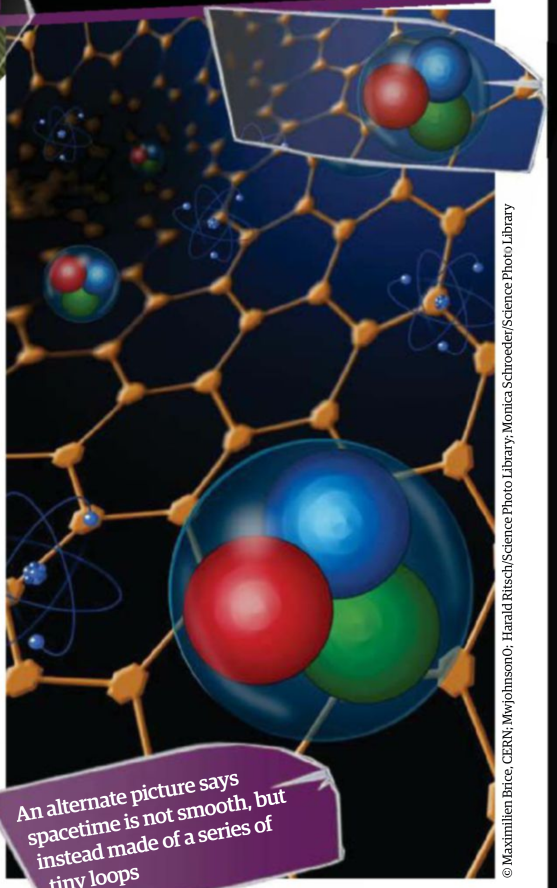
The attraction of this theory – called modular spacetime – is that it might help solve another long-standing problem in theoretical physics regarding something called locality, and a notorious phenomenon in quantum physics called entanglement. Physicists can set up a situation whereby they bring two particles together and link their quantum properties. They then separate them by a large distance and find they are still linked. Change the properties of one and the other will change instantly, as if information has travelled from one to the other faster than the speed of light in direct violation of relativity. Einstein was so perturbed by this phenomenon that he called it 'spooky action at a distance'.

Modular spacetime theory can accommodate such behaviour by redefining what it means to be separated. If spacetime emerges from the quantum world, then being closer in a quantum sense is more fundamental than being close in a physical sense. “Different observers would have different notions of locality,” says Minic, “it depends on the context.” It's a bit like our relationships with other people. We can feel closer to a loved one far away than the stranger who lives down the street. “You can have these non-local connections as long as they are fairly small,” says Hossenfelder.

Freidel, Leigh and Minic have been working on their idea for the last five years and they believe they are slowly making progress. “We want to be conservative and take things step-by-step,” says Minic, “but it is tantalising and exciting”. It's certainly a novel approach, one that looks to ‘gravitationalise’ the quantum world rather than quantising gravity as in LQG. Yet as with any scientific theory it needs to be tested. At the moment the trio are working on how to fit time into their model.

This may all sound incredibly esoteric, something only academics should care about, but it could have a more profound effect on our everyday lives. “We sit in space, we travel through time, and if something changes in our understanding of spacetime this will impact not only on our understanding of gravity but of quantum theory in general,” says Hossenfelder. “All our present devices only work because of quantum theory. If we understand the quantum structure of spacetime better that will have an impact on future technologies – maybe not in 50 or 100 years but maybe in 200,” she says.

The current monarch is getting long in tooth and a new pretender is long overdue, but we can't decide which of the many options is the most likey to succeed. When we do, the resulting revolution could bear fruit not just for theoretical physics, but for all.



An alternate picture says spacetime is not smooth, but instead made of a series of tiny loops

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Explorer's Guide

Alpha Centauri

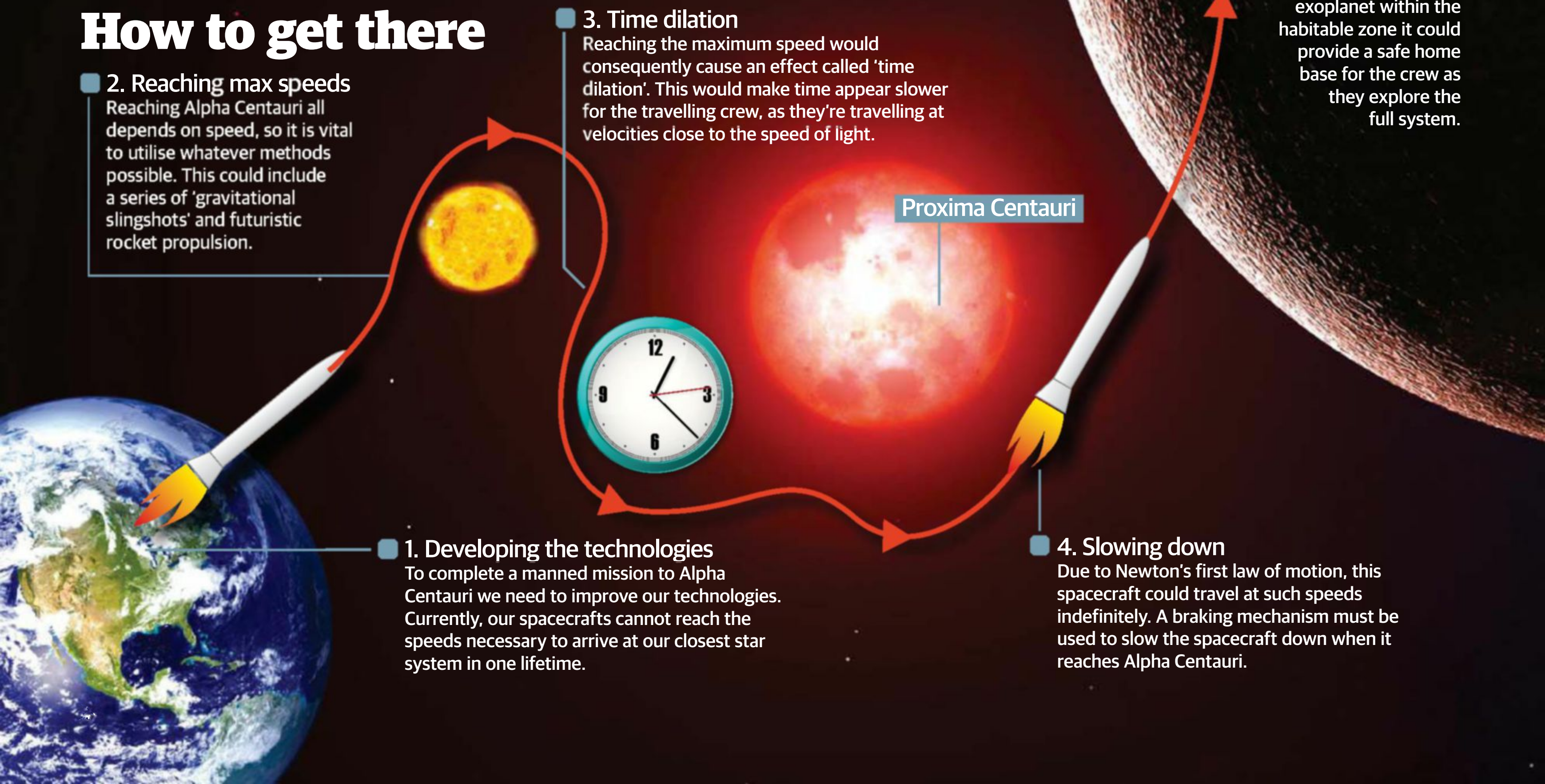
Our neighbouring star system is the next frontier of cosmic exploration

Alpha Centauri is the closest star system to us, with it being just over four light years away. The star system contains three stars in total, but it is Alpha Centauri A and Alpha Centauri B that shine the brightest in the constellation of Centaurus. Alpha Centauri A and B have similar masses, and therefore similar luminosities, which combine to create a visual apparent magnitude of -0.27. The brightest of the bunch is Alpha Centauri A, which is a G2V star - the same as our Sun - and Alpha Centauri B shines slightly dimmer, as it is a K1V star.

The stars A and B have 1.1 and 0.9-times the mass of the Sun respectively, and because of their similar masses, one does not orbit the other. In this case, they both orbit a common 'centre of mass', classifying Alpha Centauri AB as a binary star system. Due to this double orbit around a centre of mass, the distance of the two stars varies greatly. The closest approach between the stars is 11 Astronomical Units (AU) - one AU is the distance between the Sun and Earth - which is roughly the same distance at the Sun and Saturn. The furthest distance between the two stars stands at a massive 35 AU, which is similar to the distance from the Sun to Pluto.

Proxima Centauri is the third companion of the Alpha Centauri star system, and is the smallest stellar sibling. It's an M-type dwarf star with only 0.1 times the mass of the Sun, and sits at a substantial distance of 15,000 AU from its companions. This extensive orbit makes astronomers question whether it's entirely gravitationally bound. The broad orbital distance makes Proxima the closest star to Earth, with a distance of 4.24 light years away. Scientists worldwide rejoiced in August 2016, when news of a potentially habitable, Earth-like planet - later dubbed Proxima Centauri b - was discovered.

How to get there



1. Developing the technologies

To complete a manned mission to Alpha Centauri we need to improve our technologies. Currently, our spacecrafts cannot reach the speeds necessary to arrive at our closest star system in one lifetime.

2. Reaching max speeds

Reaching Alpha Centauri all depends on speed, so it is vital to utilise whatever methods possible. This could include a series of 'gravitational slingshots' and futuristic rocket propulsion.

3. Time dilation

Reaching the maximum speed would consequently cause an effect called 'time dilation'. This would make time appear slower for the travelling crew, as they're travelling at velocities close to the speed of light.

4. Slowing down

Due to Newton's first law of motion, this spacecraft could travel at such speeds indefinitely. A braking mechanism must be used to slow the spacecraft down when it reaches Alpha Centauri.

5. Exploring Proxima Centauri b

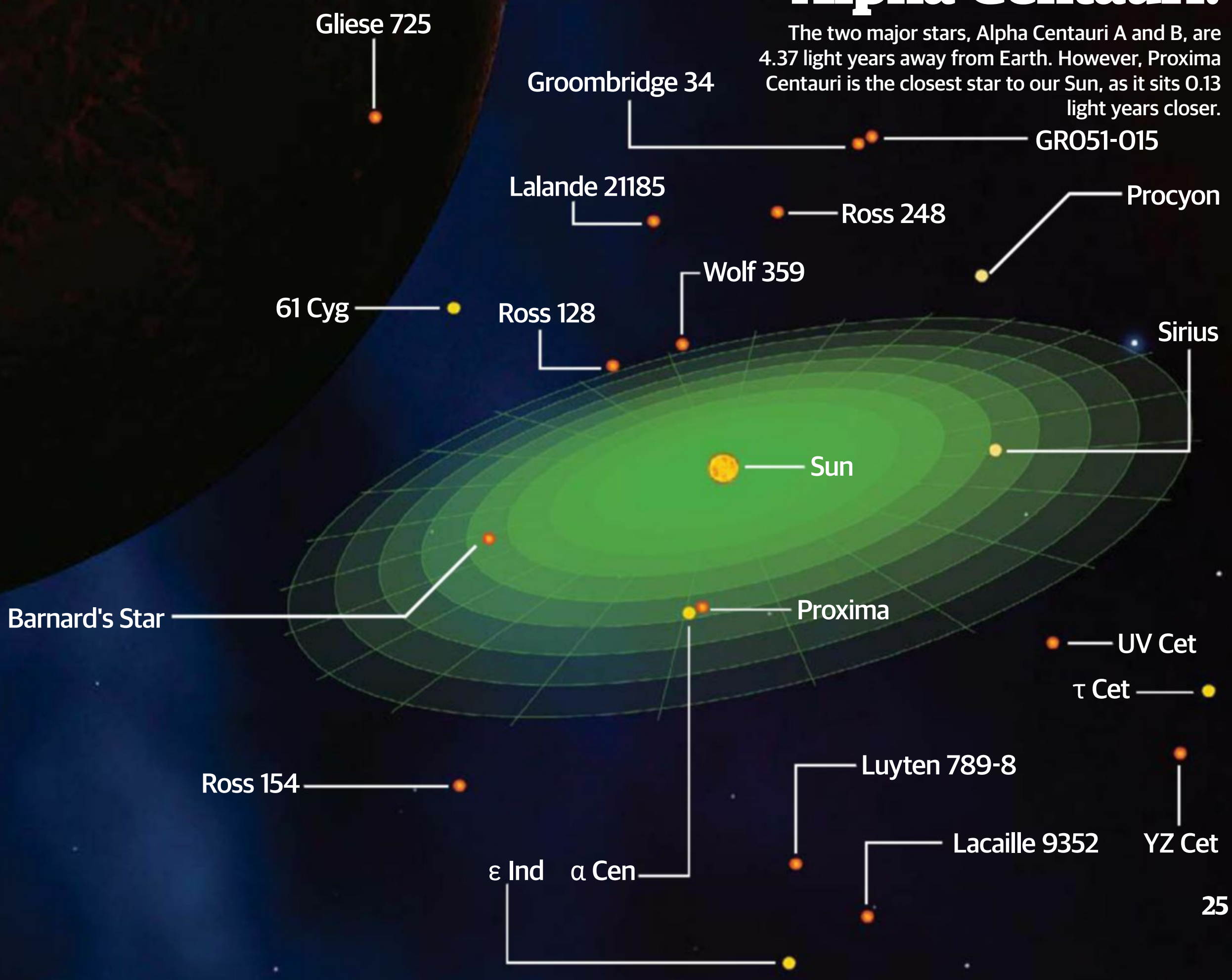
The first stop would be at Proxima Cenatauri b. As it is a super-Earth exoplanet within the habitable zone it could provide a safe home base for the crew as they explore the full system.

How big is the Alpha Centauri system?

The distance of Proxima from Alpha Centauri AB is 300 times the orbit of Pluto from the Sun!

How far away is Alpha Centauri?

The two major stars, Alpha Centauri A and B, are 4.37 light years away from Earth. However, Proxima Centauri is the closest star to our Sun, as it sits 0.13 light years closer.



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Top sights to see on Proxima Centauri b

Although our modern telescopic technologies have come along leaps and bounds in recent years, it's still not good enough to resolve the full picture of Alpha Centauri from where we are. However, in recent times, a planet has been discovered orbiting Proxima Centauri (labelled as Proxima Centauri b), which could potentially be habitable.

If future spaceflight allowed us to reach our closest star within a lifetime, this exoplanet would the first place to visit. It shouldn't be too hard to find, as it orbits the host star at 0.05 AU, which is closer to the star than Mercury is to the Sun. Because of the star's smaller mass, it therefore has less fuel to burn, which creates a far less energetic star compared to our Sun. As the star creates less intense light, the area from the star where water could exist as a liquid - also known as the habitable zone - is much closer to the star. Fortunately, Proxima Centauri b sits within this habitable zone, and as we all know, liquid water is vital for life, which is why astronomers are so fond of this target.

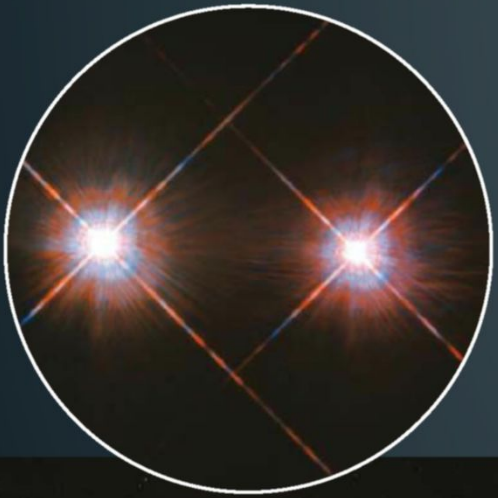
As for the surface conditions on the Earth-like exoplanet, it can only be speculated until the atmosphere of the planet can be analysed. The James Webb Space Telescope is due to launch in 2018, and this will have the resolving capabilities to probe the atmosphere of Proxima Centauri b, but until then, the terrain of the planet is a mystery.

If you were to stand on the surface of this planet, you could gaze upon many celestial spectacles. Not only would the star appear massive in the sky, but because of its close proximity, the likelihood of the planet being tidally locked - when one side of the planet faces the star at all times - is extremely high. If you've had enough of the dayside and the three gleaming stars, there is the chance to take a trip to the nightside of the planet, opening up a completely new, beautiful, but strangely familiar view.

Because Proxima Centauri isn't far away from us, there wouldn't be much difference in the constellations. However it would be very interesting to know what our Sun would look like as part of a constellation. Astronomers have deduced that our Sun would fit into the constellation of Cassiopeia, and it would appear extremely bright with an apparent magnitude of 0.5. It would be bright enough to add to the original and recognisable 'W' of Cassiopeia, making it more of a zigzag.

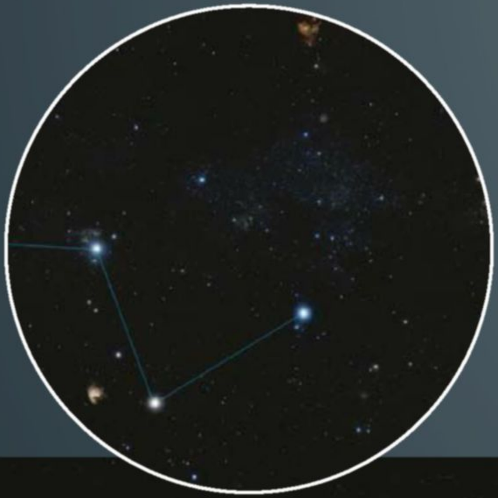
Binary stars

The second brightest star in the sky of Proxima b would be Alpha Centauri A and B. They are a binary star system that completes one orbit every 80 years.



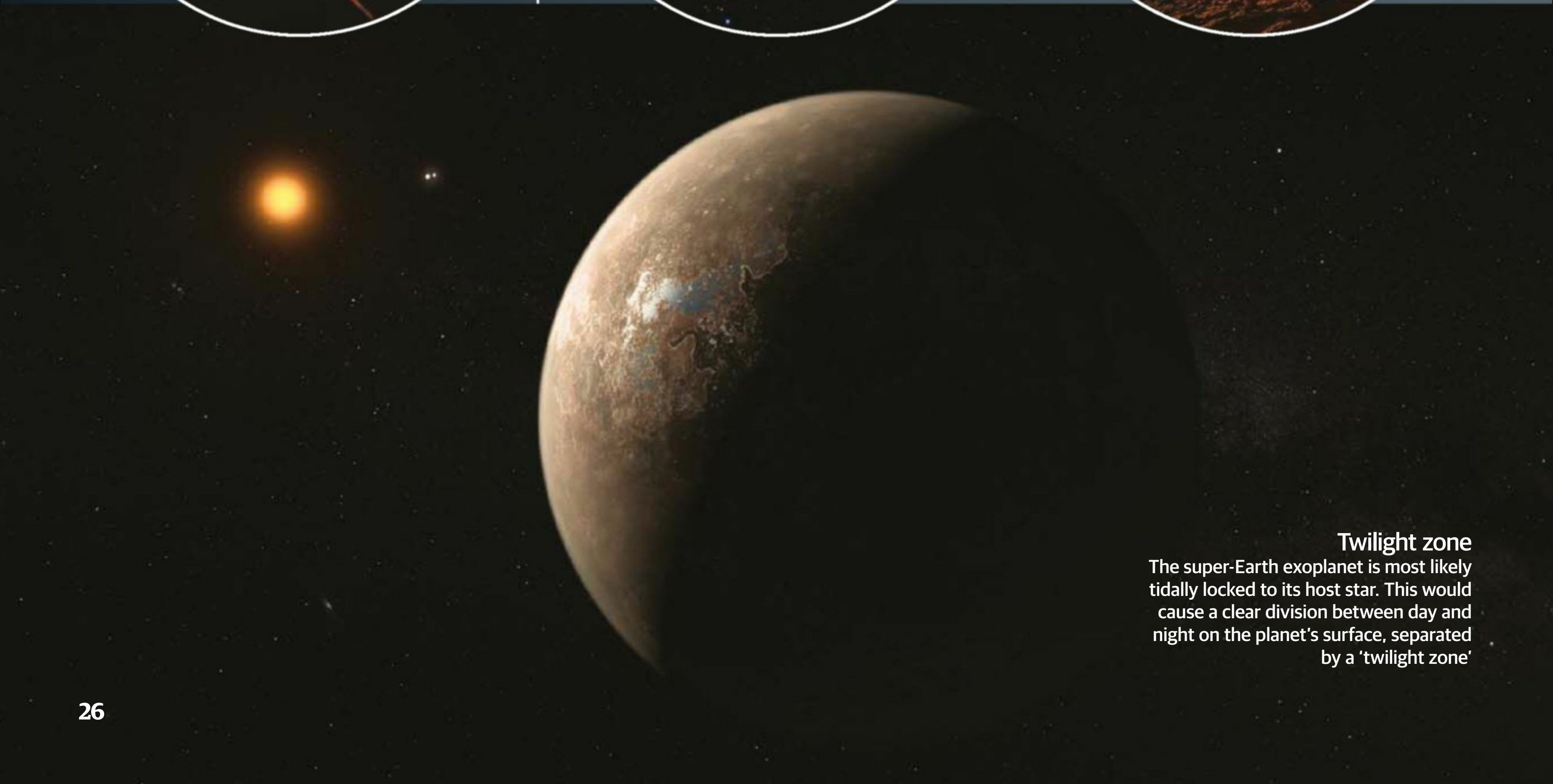
The Sun in Cassiopeia

From Alpha Centauri, our Sun would appear bright as an alien celestial object, changing the famous Cassiopeia 'W' formation to more of a zigzag.



Massive sun

Proxima Centauri b orbits its parent star at a relatively tiny distance of 0.05 AU. This would make its star appear massive in the sky.

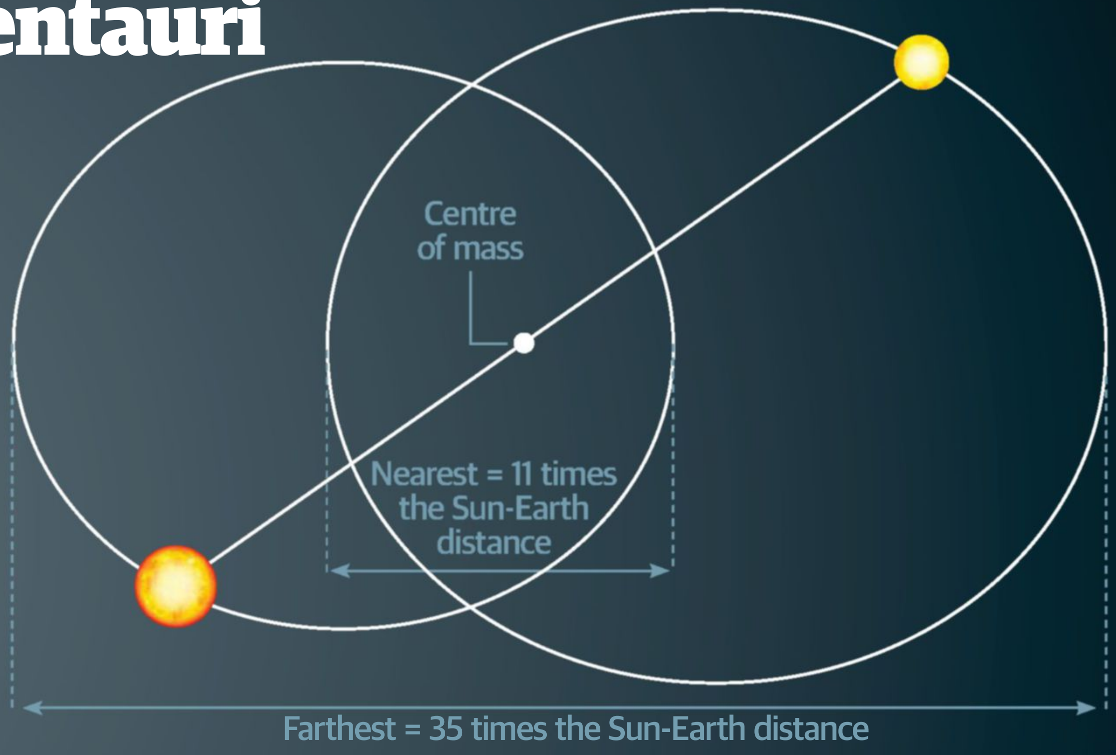


Twilight zone

The super-Earth exoplanet is most likely tidally locked to its host star. This would cause a clear division between day and night on the planet's surface, separated by a 'twilight zone'

Alpha Centauri AB orbit

The two primary stars in this system, Alpha Centauri A and B, both have similar Sun-like masses. This causes an unusual orbit to what we know, as one body doesn't have the superior mass to its secondary object. In this case, they both orbit the same point known as the 'centre of mass'. This is the point where the gravity, and the masses, of both stars are equal.


Centre of mass
Nearest = 11 times the Sun-Earth distance
Farthest = 35 times the Sun-Earth distance

Alpha Centauri in numbers

1689
The year when Alpha Centauri was discovered to be a binary star system

550,000
Orbital period of Proxima b in years

234 Kelvin/-39Celsius
Equilibrium temperature of Proxima b

2016
Discovery of Proxima Centauri b

1915
The year Proxima Centauri was discovered

5.25billion
Average age of the three stars

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VE WHAT IT O BE AN ONAUT?

A career in space is not for everyone – but it just might be right for you

Written by Rebecca Caddy

NASA plans to reach Mars by the 2030s, and sci-fi movies and TV shows are making space exploration look more exciting than ever, so: have you ever asked yourself if you're cut out for life as an astronaut?

In 2016 NASA received a record 18,300 applications from budding astronauts, compared to 6,000 in 2012, and it's no surprise becoming an astronaut is appealing. Science-fiction movies make life in space look star-shatteringly exciting, from *The Martian*, which NASA experts consulted on, to the adventures of the crew of the Enterprise in *Star Trek*.

And real life is fast catching up. NASA's Journey to Mars is well underway with a plan that will see astronauts landing on an asteroid in the 2020s and reaching Mars' orbit by the 2030s.

Increasingly, space agencies aren't the only space workplaces either. Private companies like SpaceX and Virgin Galactic will soon offer budding astronauts the chance to work - and even holiday - among the stars.

But becoming an astronaut is difficult and time-consuming, and very few people are up to the job. Still think you might have what it takes? Get ready to launch your application into the stratosphere.

What to put on your application

Before beginning the rigorous training to prepare you for space, there are a strict set of entry requirements you have to meet. These differ depending on which space agency you want to work for, whether that's NASA in the United States or the European Space Agency (ESA) in the UK and the rest of Europe.

Both the ESA and NASA require a degree in engineering, science or mathematics, as well as 1,000 hours of pilot-in-command time in an aircraft or three years of related experience.

You also need to be physically up to the job. NASA puts would-be astronauts through a 'long-duration astronaut physical,' which includes fitness and eye tests. Space agencies are looking for recruits who are fit and healthy so they can cope with the demands of space, and are less likely to become ill when they're millions of miles from Earth.

We spoke to Kevin Fong, a Doctor at UCL hospital specialising in anaesthesia and pre-hospital care, who has worked with NASA to ask important medical questions about space travel, and ensure flight-readiness of crews. He tells **All About Space**: "There are a lot of physical requirements, but personality is just as important, such as people working together as part of a team. We're also looking for evidence of where real decisions have real consequences."

So personality, physical fitness, experience and education are all required, but often it can depend on what the agency is looking for during any given recruitment push. Fong explains: "Space agencies will often select astronauts depending on what the mission requires. Long-duration missions will need a broader skill set than say, the test pilots who crewed the Apollo missions, for example."

He continues to explain that "in the future there'll be more exploration class missions, so we'll need to find the right people. It works like any hiring process at any other company."

> "There are a lot of physical requirements, but personality is just as important"
>
> **Dr Kevin Fong**

ESA astronaut Thomas Pesquet taking part in training on the Soyuz docking simulator

The long journey into space

To understand the hard work involved in preparing to become an astronaut, **All About Space** spoke to Abigail Harrison – or 'Astronaut Abby' as she's become known on social media. The aspiring astronaut has spoken publicly for years about her dreams to become an astronaut and is a STEM and space ambassador, she also has her own website documenting her journey: **astronautabby.com**.

"Right now, the biggest thing I'm doing is focusing on my education," Abby tells **All About Space**. "I'm in my third year at Wellesley college, and also working in a Mars astrobiology internship for a NASA funded project. I'll apply at the beginning of forth and final year of college for astrobiology PhD programs, and after graduation I'll start working on my PhD. Building my career is really the most essential part of preparing to apply for the NASA astronaut corps."

Abby's education is bound to impress NASA, but will only get her so far. **All About Space** asked how else she's making her application shine. "I am also working on my private pilot license, advanced scuba diving training, learning Russian and Chinese and gaining many other skills that will strengthen my application," she says.

© ESA-Stephane Corvaja, 2016; NASA

NASA astronaut Michael Hopkins uses a virtual reality headset in the Space Vehicle Mock-up Facility

Would you pass a health check?

How tall are you?
A: Under 5'1"
B: Between 5'1" and 6'2"
C: I'm over 6'2"

A

C

You're not likely to become an astronaut
Every space agency has a slightly different set of astronaut height requirements. That means if you didn't make the cut this time you might still be in with a chance, especially as mission demands shift over the next few years. You're in with the best chance if you measure up between 5'1" and 6'2".

B

Do you have perfect vision?
A: Yes
B: No

B

You're not likely to become an astronaut
Most space agencies are looking for candidates with 20/20 vision. As ESA points out on its website, most disqualifications during the recruitment process are due to problems with candidates' eyesight – and that's hardly surprising.

A

Do you have a medical condition?
A: Yes
B: No

A

You're not likely to become an astronaut
Each medical condition is different and often assessed on a case-by-case basis, but if you have a disease, psychiatric condition or a disability it may stop you from becoming an astronaut. Although being up in space isn't necessarily dangerous, you need to be as fit and healthy as possible so you won't need medical attention.

B

Do you smoke?
A: Yes
B: No

A

You're not likely to become an astronaut
You wouldn't be able to drink, smoke or take drugs on the job or deal with the emotional and physical symptoms of withdrawal. Of course if you're willing to work on beating your addiction before you apply there's a chance you'll be considered, but that would require assessment.

B

Do you enjoy fitness and exercise?
A: Yes
B: No

B

You're not likely to become an astronaut
Being an astronaut is very physically demanding, from the training at the start that involves lots of high-intensity cardio, to carrying out missions in space, through to the physiological effects of weightlessness. This means if you don't enjoy working out you could still become an astronaut, but you're going to have to do more cardio.

A

You could be an astronaut
Well done, you've passed the first set of health tests, which means there's a chance you could become an astronaut one day. You enjoy exercise, your vision is laser sharp, you're the right height and there aren't any medical conditions that could cause problems for you or future missions when you're up in space.

Astronaut candidate Anne McClain learns survival skills as part of an extensive training programme

ESA's French astronaut Thomas Pesquet during a water survival training session

Astronaut candidate Christina Hammock starts a fire as part of an extensive training programme

ESA astronaut Matthias Maurer takes part in a staple part of training – sea survival

Astronauts take part in an emergency bailout training session using small life rafts

Astronauts conduct vestibular tests on tilt tables as part of their prelaunch training

Time to begin training

After making it through the initial entry requirements, candidates are invited to take part in a screening process. In 2008 when British astronaut Tim Peake began this process, ESA took roughly 900 candidates through a series of tests before whittling them down to just ten over the course of a year.

But making it through the application process, the screening process and the excitement of being one of the lucky ten is only the beginning. You can only become a full-fledged astronaut if you successfully complete the next two years of training.

This training involves different activities depending on which space agency you're working for, but it generally includes military water survival training to replicate zero gravity, emergency medical training, scuba diving, swimming tests and exposure to different kinds of atmospheric pressure.

At a NASA Symposium in Dallas on YouTube, NASA Astronaut Dorothy Metcalf-Lindenburger said, "In one training scenario we were in a swimming pool, and turned over underwater in a mock spacecraft and had to get out of any door or window, the second time the door or window they assigned and the third time you had to do it blindfolded [...] That was my least favourite day on the job."

A lot of training involves activities that you wouldn't necessarily experience in space, but can utilise a lot of the same skills. In a NASA podcast about astronaut training, astronaut Randy Bresnik spoke about his caving adventures. "So you start out, just like on any training, with basic caving stuff, and rappelling and climbing. Then you went into a day where you're in really narrow caves and it's really winding about, getting lost, and navigation, and being able to go through squeezes and navigating through tiny areas of the cave to be able to overcome any claustrophobia," Bresnik said. "It was really applicable to what we do in space," he explained, "because in

ESA astronaut Samantha Cristoforetti trains for her robotic arm duties at the Virtual Reality Lab

ESA astronaut Paolo Nespoli participating in spacewalk training in the Partial Gravity Simulator (POGO)

ESA's astronaut candidates from 2010 experience weightlessness in between training sessions

ESA astronaut Thomas Pesquet participating in underwater spacewalk training at NASA's Johnson Space Center

space, you don't know what time it is, because every 45 minutes, you get a sunrise, and then a sunset, and that happens 16 times a day."

There's also a considerable amount of time spent in the classroom learning about space and learning Russian, so you can talk with other astronauts on board the International Space Station (ISS), many of which come from the Russian agency, Roscosmos.

Once training is complete, qualified astronauts are still unlikely to go up into orbit for years. They complete simulated spacewalks, train with international partners and learn more to prepare them for their designated role. Retired Air Force pilot Colonel Gregory Johnson from the Johnson Space Flight Centre explained in an interview on the NASA YouTube channel: "Once you become an astronaut, you specialise in your particular area. In my case it was operating the Space Shuttle, learning to land, rendezvous two different objects, including the ISS and learning to operate the robotic arms on the ISS and the Space Shuttle."

Once you're selected for a flight, the mission training may take another couple of years, which will involve further simulations, classroom training and way more learning so that you are fully prepared.

Astronaut Randy Bresnik spoke about the training involved to prepare astronauts for life on board the ISS. "There's a lot of station training because you've got to be able to do everything. You've got to be able to execute the payloads and experiments. At the same time, you've got to be able to do the Earth's observation."

There's also a significant amount of media and interview training, as well as learning to do many other jobs, as Bresnik tells **All About Space**. "You've got to be able to do the events, so talk to people down here on the earth and share the experience, on top of being the janitor. You've got to clean up the vents and wipe down the handrails and make sure the station is clean. We've got to be able to fix things that break. [If the] toilet breaks, you're not calling the plumber. You are the plumber!"

> "Once you become an astronaut, you specialise in your particular area. In my case it was operating the Space Shuttle, learning to land, rendezvous two different objects"
>
> **Colonel Gregory Johnson**

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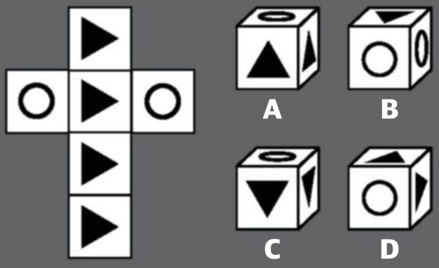
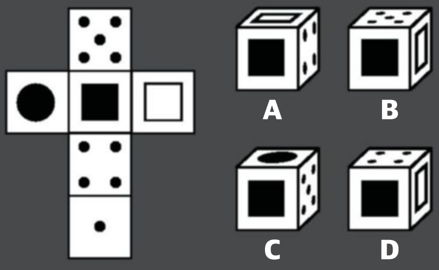
Test your spatial awareness

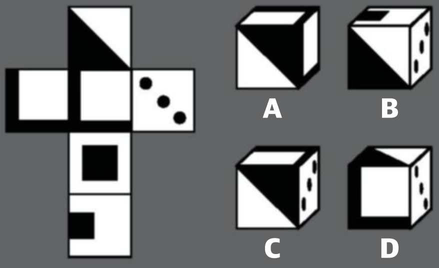
Scenario 1
Which cube cannot be made from the unfolded cube?



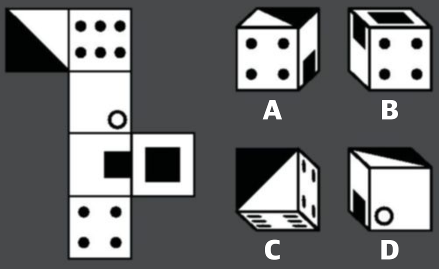
Scenario 2
Which cube cannot be made from the unfolded cube?



Scenario 3
Which cube cannot be made from the unfolded cube?



Scenario 4
Which cube cannot be made from the unfolded cube?



Answers: 1. B // 2. D // 3. C // 4. D

How would you respond in the following situations?

You're going about your daily tasks and you see a small fire has started aboard the spacecraft in front of you. *What do you do?*

A: Fight the fire with an extinguisher
B: Call mission control on the ground
C: Raise an alarm and let everyone else know
D: Leave the area straight away

Phew, the fire is out. Well done. Once all the crew members are safe and the area looks safe, what should your next step be?

A: Figure out a way to leave the spacecraft
B: Investigate at the source
C: Stay far, far away from the affected area
D: Call mission control on the ground

A solar flare has directed dangerous levels of radiation toward your spacecraft. What do you tell the rest of the crew to do?

A: Evacuate the spacecraft
B: Put on a radiation absorbing suit
C: Go to a special space within the spacecraft that absorbs radiation
D: Keep working because a bit of radiation never hurt anyone

Debris has hit the hull of the ISS, which creates a hole and may cause depressurisation. *What do you do?*

A: Tell the crew to get into their spacecraft and close the hatches
B: Try and plug the hole quickly
C: Contact mission control
D: Put on an oxygen mask

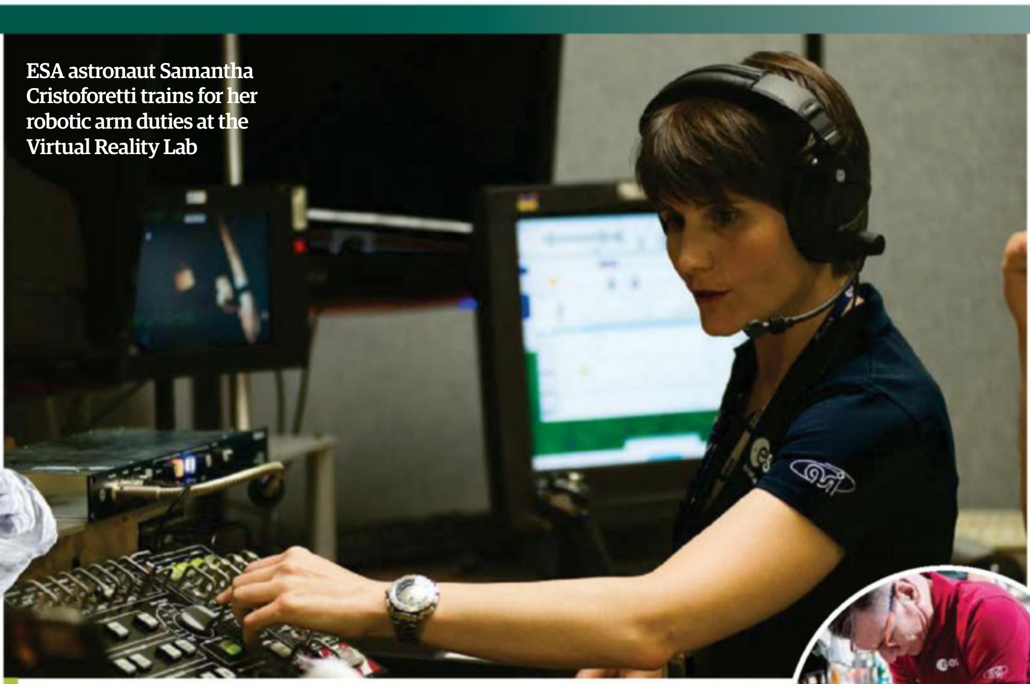
Answers

1. Correct answer: C then D
The first step in astronaut emergency training is often to warn others, followed by leaving the affected area and starving the fire of oxygen.

2. Correct answer: B and D
The next step is to gather information. You need to work with crew members and mission control to find out what happened, and why.

3. Correct answer: C
There are special areas of the ISS that astronauts can go to that help to stop radiation from attacking your body.

4. Correct answer: A
You should return to your spacecraft, which acts as a lifeboat, and close hatches to minimise damage in case the hole is big.



ESA astronaut Samantha Cristoforetti trains for her robotic arm duties at the Virtual Reality Lab

ESA astronaut Samantha Cristoforetti during a simulation inside the full-scale mockup of the Soyuz capsule

Skills you can take with you

If you don't make it through the astronaut application process, or training, all might not be lost. Mike Mongo, astronaut teacher and author of *The Astronaut Instruction Manual* tells **All About Space**: "The modern space industry is also made up of private space companies such as Blue Origin, SpaceX, Virgin Galactic, Orbital ATK, The Space Company, Bigelow Aerospace and many others, all of which are being built on business models that'll require more astronauts."

These companies are likely to require similar kinds of candidates, but as Mongo points out, they may need a more diverse bunch of people. "Pretty much every line of work we do on Earth will soon have parallel positions in space," Mongo tells **All About Space**. "For instance, Bigelow Aerospace just completed a year-long test of a space habitat technology the company intends to use for a space hotel."

He continues "so all types of personality traits, physical characteristics and cultural backgrounds are in demand for becoming an astronaut. Diversity of talents as well as diversity of people will be the next big determinant of astronaut selection."

Do you have the right stuff?

The application process favours the best of the best, the training is exciting but extremely demanding and the competition is as fierce as it gets. But with the right experience, mindset and a love for physical challenges, you could become the next Tim Peake or Peggy Whitson.

The 2017 NASA astronaut class are undergoing a training programme at the Johnson Space Centre

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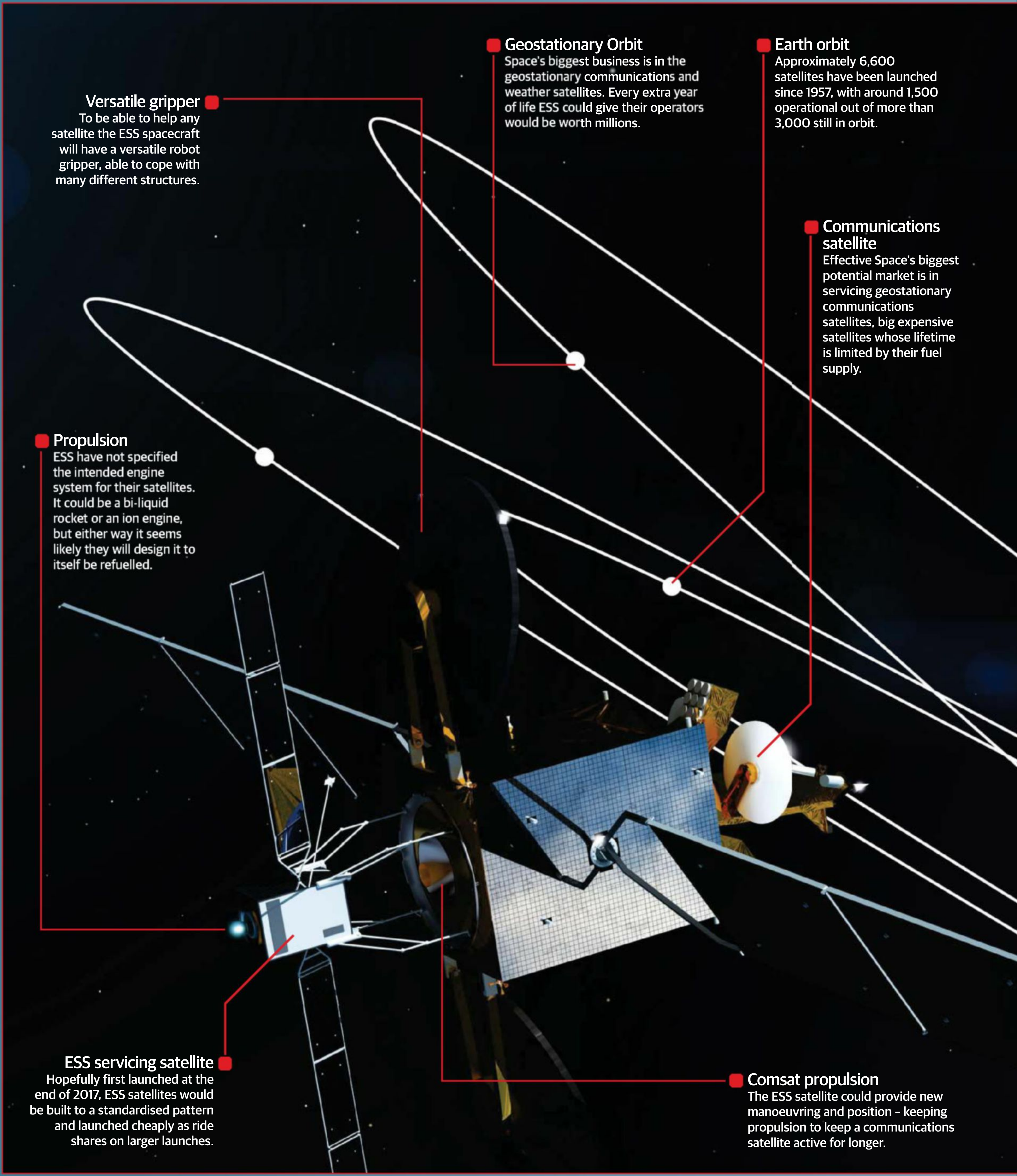


Geostationary Orbit

Space's biggest business is in the geostationary communications and weather satellites. Every extra year of life ESS could give their operators would be worth millions.

Earth orbit

Approximately 6,600 satellites have been launched since 1957, with around 1,500 operational out of more than 3,000 still in orbit.

Versatile gripper

To be able to help any satellite the ESS spacecraft will have a versatile robot gripper, able to cope with many different structures.

Communications satellite

Effective Space's biggest potential market is in servicing geostationary communications satellites, big expensive satellites whose lifetime is limited by their fuel supply.

Propulsion

ESS have not specified the intended engine system for their satellites. It could be a bi-liquid rocket or an ion engine, but either way it seems likely they will design it to itself be refuelled.

ESS servicing satellite

Hopefully first launched at the end of 2017, ESS satellites would be built to a standardised pattern and launched cheaply as ride shares on larger launches.

Comsat propulsion

The ESS satellite could provide new manoeuvring and position – keeping propulsion to keep a communications satellite active for longer.

Spaceside servicing & delivery

New space start-up Effective Space Solutions are hoping to start servicing satellites

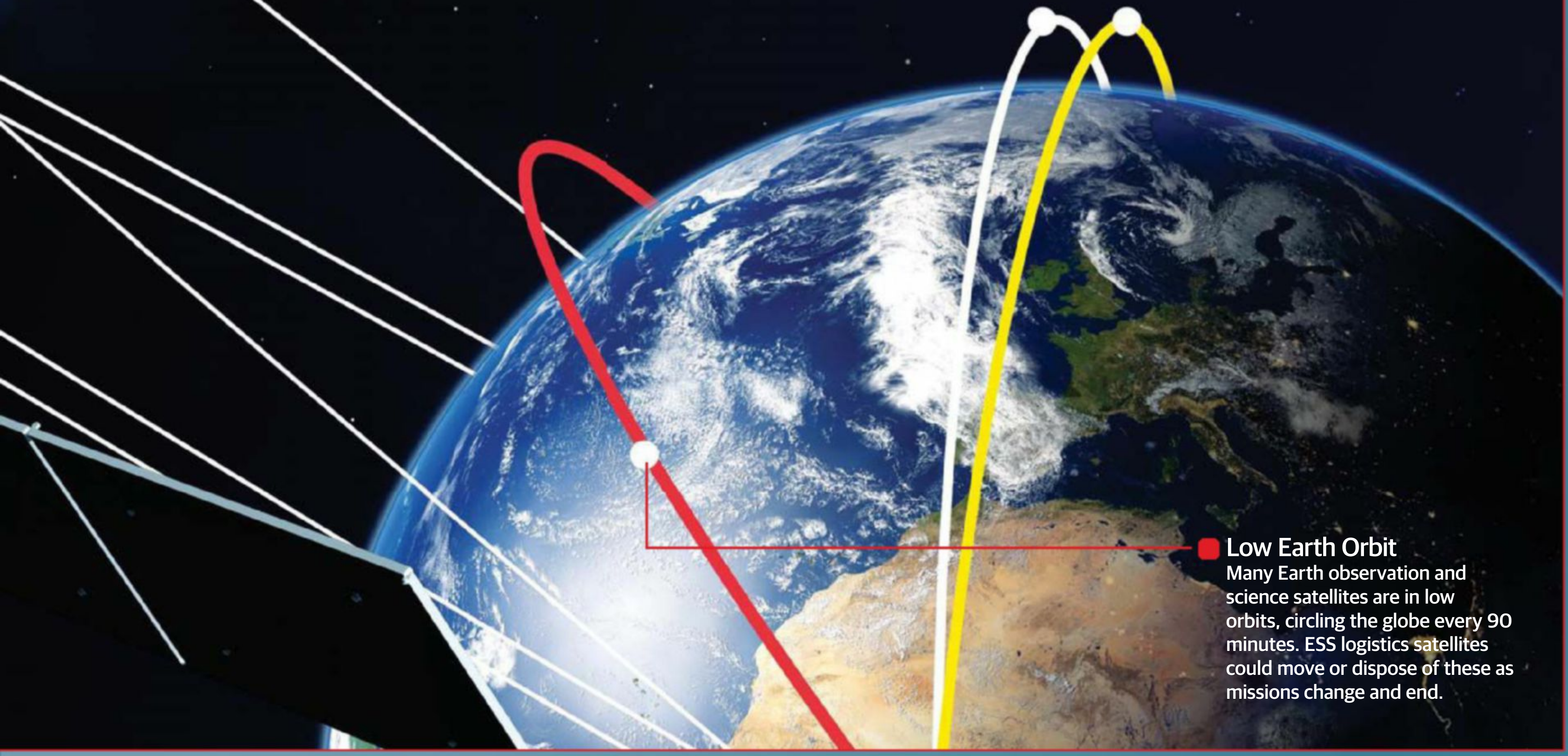
In 2013 Arie Halsband, a former general manager with Israel Aerospace Industries, set out to design something long discussed but only ever actually achieved by the Space Shuttle - a way of servicing orbiting satellites. Now his start-up Effective Space Solutions (ESS) is expecting to launch their first hardware in the next six months.

Traditionally, satellites have been built as single use devices that must last for years or decades unattended, before simply shutting down. But, as satellite constellations are getting bigger and bigger, and Earth orbit is getting more and more crowded, there is an opportunity for someone to refuel, repair, repurpose or dispose of satellites. Halsband is planning to fill this niche.

In space, repair and retrieval has been done during the Space Shuttle programme, but only for very important satellites like the famous Hubble Space Telescope servicing missions; this is because the Shuttle was a very expensive way of doing anything. Halsband will be approaching the problem from the other direction: ESS has designed a standardised micro satellite that can be inexpensively mass-produced and launched on ride shares (when small payloads are launched in the spare capacity of a large satellite launch). The micro satellites have a versatile robot handling system, "Our docking mechanism is non-intrusive and is generic enough to allow us to dock to any existing communication satellite," explains chief technical officer Meidad Pariente. Once attached, the ESS mini satellites could provide new propulsion - taking over the position keeping and orientation duty for an expensive communications satellite that is running low on fuel. Perhaps most significantly the micro satellites could offer an inexpensive way of disposing of old satellites, clipping on and then either pushing them further out into a graveyard orbit, or slowing them so they fall and burn up.

Life extension and disposal can help satellite operators get much more value out of their fleet, and avoid the potential costs of collisions with old hardware. The flexibility of the ESS approach also offers the possibility of selling and redirecting a satellite already in space. A new operator could buy an existing satellite, then have ESS go and move it to the orbit needed. ESS has successfully raised considerable funding for their project already, enough to make real progress with real hardware. Further funding is in the works, and Halsband is hoping to launch the first ESS satellites by the beginning of 2018.

Halsband and ESS are thought to have ambitions beyond Earth orbit, too. Once an inexpensive capability of production and launch is established (and launch is likely to get much cheaper in the near future as SpaceX, Blue Origin and RocketLab shake up the industry) ESS service satellites could push payloads out to stations at the Lagrange points, or to lunar outposts. Indeed, if their satellites are designed to be themselves serviced and refuelled (as yet unconfirmed), ESS could build up a considerable fleet of reusable space delivery drones!



Low Earth Orbit
Many Earth observation and science satellites are in low orbits, circling the globe every 90 minutes. ESS logistics satellites could move or dispose of these as missions change and end.

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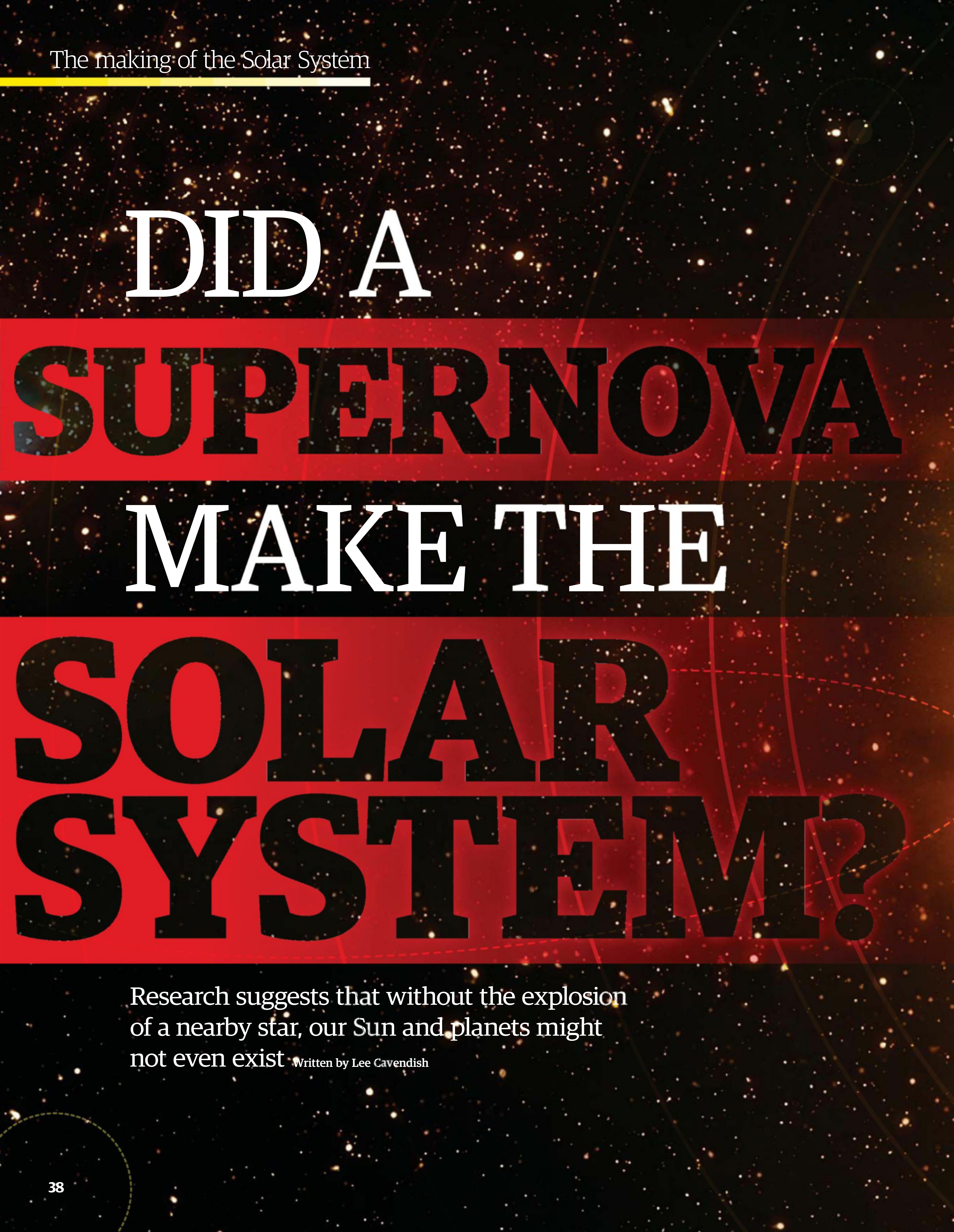
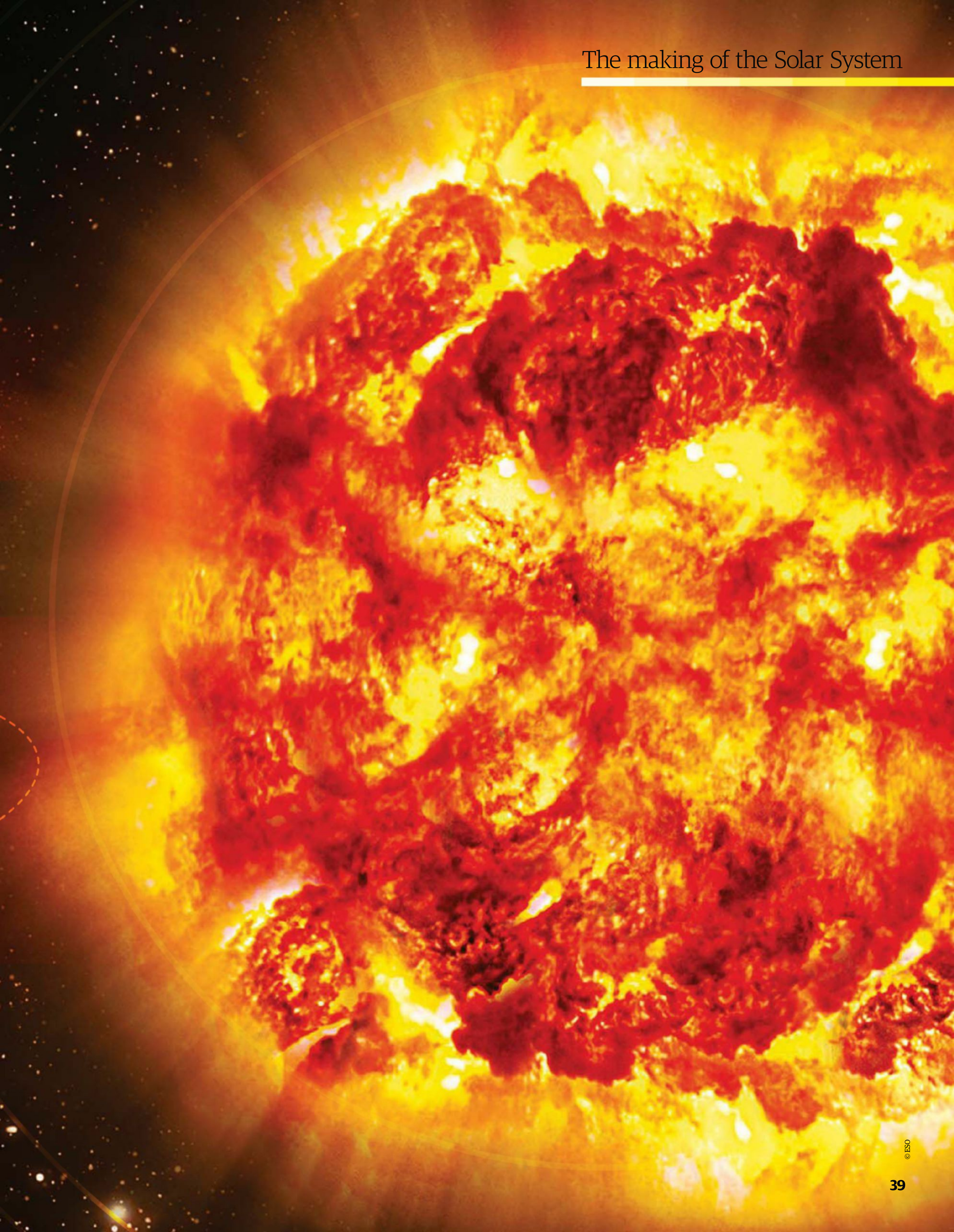


DID A SUPERNOVA MAKE THE SOLAR SYSTEM?

Research suggests that without the explosion of a nearby star, our Sun and planets might not even exist

Written by Lee Cavendish



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In the vast neighbourhood of stars that is our Milky Way, our home sits 27,000 light-years from the galactic centre in the 'Orion Arm'. Our Solar System is home to a main sequence star, eight incredibly varied planets, countless moons, dwarf planets and other objects we have become more accustomed to over the years.

The diversity across the Solar System presents a visual masterpiece. The question we should be asking – as we should with everything in the universe – is, "how did it get there?" This is a question that has perplexed scientists for decades when delving into the origins of the Solar System. No matter how many theories scientists come up with, they need to explain multiple complex aspects. For example, how do you explain the Sun being at the centre of all mass? Why did the planets form orbiting a level plane? But also, where did cosmic metals (any element heavier than helium) come from?

The leading theory for all of this is the 'Nebula Hypothesis'. This theorises that the Solar System began as a giant, diffuse cloud of gas (akin to the Orion Nebula), until an event occurred which caused its collapse 4.6 billion years ago. Continuous contraction then transformed the core of the cloud into a young, small star, also known as a protostar. While this happened, the surrounding material formed a disc that spun around the protostar, known as a protoplanetary disc. This protoplanetary disc contained material that had enough angular momentum to not fall into the protostar, which would have almost resembled Saturn and its rings, just on a much larger scale.

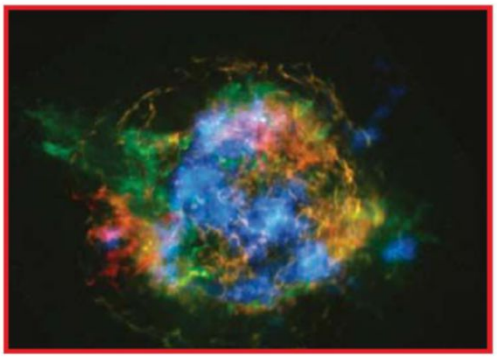
Roughly 10 million years later, the protostar had eaten enough of the surrounding gas to produce gigantic amounts of pressure in the core. The insane pressure increased the core temperature to the point where thermonuclear fusion finally began, ushering in the era of our main sequence star. Nonetheless, there was more construction to do: there was the formation of planets still to come.

Our planets all stem from the surrounding protoplanetary disc that revolved around our early Sun. This plane of gas swirling around the protostar began to cool, causing the gas to clump together – similar to how dust bunnies arise in a normal household. As these tiny clumps of rock travel around the disc, their tiny gravity is enough to contract more and more surrounding material, snowballing into clumps of sizes up to 200 metres.

Further collisions between these bodies led to the formation of even larger planetesimals – much larger bodies with sizes around ten kilometres (6.2 miles) – which can also be thought of as baby planets. Continuous collisions caused perpetual expansion for the planetesimals at a rate of centimetres per year, particularly at one Astronomical Unit (AU) – the distance between the Sun and the Earth – where the rate of expansion was 15 centimetres per year. The planetesimals that could gather large amounts of mass became Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune. The remaining debris that couldn't quite gather enough mass to make up a planet is what we now know as the moons, asteroids and comets.

This explains how we got our Sun, planets and remaining debris, but this still can't fully explain the presence of the primordial metallic elements. Due to this, astronomers are pointed in the direction of a supernova explosion as the 'starting pistol'. It is known that a supernova explosion occurs at the end of a star's life; at this stage the star has already synthesised an abundance of metals in an attempt to prolong its life. Once it can't synthesise any more, the gravitational compression of the star overpowers the

The radioactive material is shown as blue in this supernova explosion. This is the material that got transferred to the Sun's primeval nebula



"No matter how many theories scientists come up with, they need to explain multiple complex aspects"

The Solar System was created 4.5 billion years ago. This is confirmed by meteorite analysis

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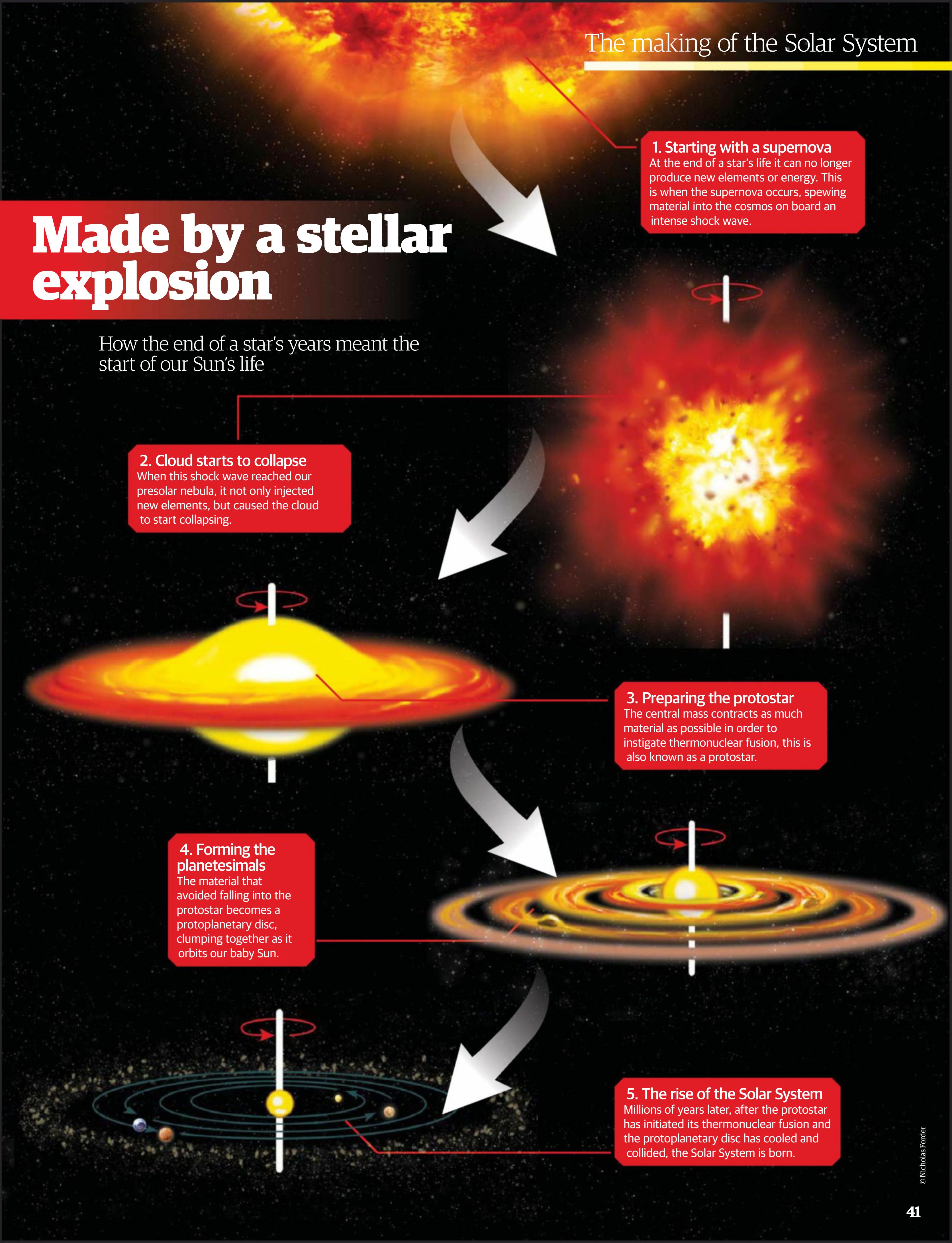
Made by a stellar explosion

How the end of a star's years meant the start of our Sun's life



1. Starting with a supernova
At the end of a star's life it can no longer produce new elements or energy. This is when the supernova occurs, spewing material into the cosmos on board an intense shock wave.

2. Cloud starts to collapse
When this shock wave reached our presolar nebula, it not only injected new elements, but caused the cloud to start collapsing.

3. Preparing the protostar
The central mass contracts as much material as possible in order to instigate thermonuclear fusion, this is also known as a protostar.

4. Forming the planetesimals
The material that avoided falling into the protostar becomes a protoplanetary disc, clumping together as it orbits our baby Sun.

5. The rise of the Solar System
Millions of years later, after the protostar has initiated its thermonuclear fusion and the protoplanetary disc has cooled and collided, the Solar System is born.

© Nicholas Forder

radiation output, leading to a spectacular explosion that casts its metallic elements into the cosmos. It is believed these elements ride the supernova shock wave through the cosmos until it interacts with another nebula, completing the stellar circle of life.

In the case of our solar nebula, a nearby supernova shock wave could have rattled our future home, as well as introducing a series of complex elements into the mix. Only recently have astronomers been able to provide evidence for such an event, and their evidence relies heavily on meteorite analysis. Meteorites are pieces of space rock that have landed on Earth. They play a vital role in understanding the origins of our universe, as they are the oldest known objects in the Solar System. The process that uncovers the age of an object is known as isotopic dating, or radioactive dating. This technique can be used to date all kinds of rocks.

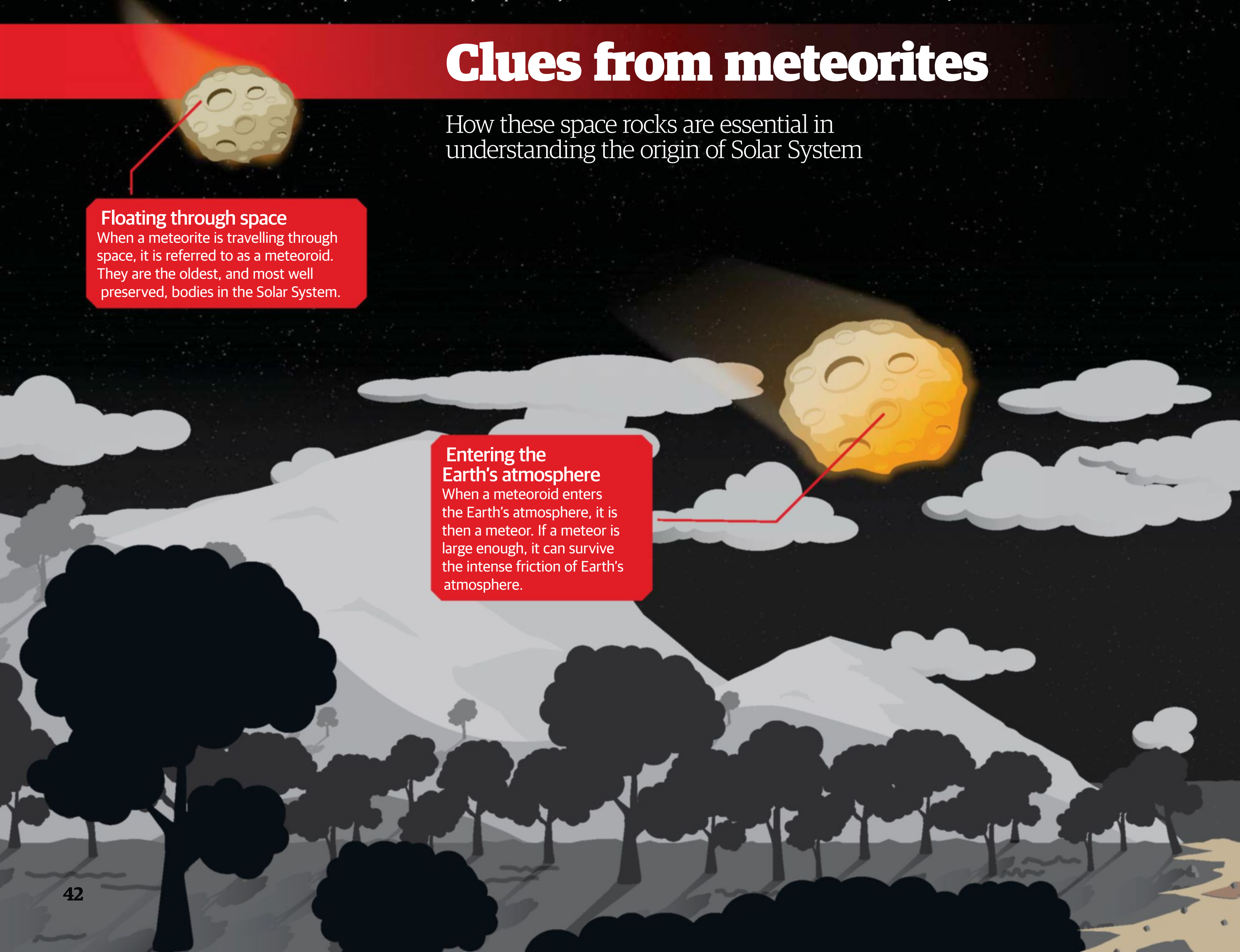
When rocks are originally formed, they are filled to the brim with radioactive elements – which can also been called isotopes. These are elements that contain the same number of protons as a known element, but a different number of neutrons, making them unstable. To stabilise the element, the isotope must eject some of its matter, creating a completely new element. The time taken to form this new element is called the 'half-life'. By determining the half-life of elements in a rock, you can then infer the age of the rock. The most common example for this is Carbon-14 isotope dating. Unfortunately this is just for previously living things on Earth, meaning this method can only date objects within the last 50,000 years. This is why astronomers use meteorites to date objects millions, or even billions, of years old. In fact, the oldest known meteorite was discovered in north-west Africa in the form of a carbonaceous chondrite meteorite, later named NWA 2364. This meteorite was analysed to be 4.568-billion-years old, give or take 170,000 years. It was supposedly formed around the time when the first solids condensed in the protoplanetary disc.

Dr Alan Boss, of the Carnegie Institute of Science, recently published a new theory regarding the origins of the Solar System. This theory explains how a supernova not only produced a shock wave powerful enough to cause the collapse of our solar nebula, but how that shock wave also injected interstellar material which originated from the dying star. This theory is based on the analysis of meteorites, and their isotopes, compared to the results of computer simulations. The isotope that was under analysis in this work was Nickel-60 – which has 28 protons and 32 neutrons – this is because it is the daughter-isotope of the original isotope, Iron-60. 90 per cent of the iron in the universe is Iron-56, which has 26 protons and 30 neutrons. Because Iron-60 has four extra neutrons it is unstable, and the eventual victim of radioactive decay.

> "Meteorites play a vital role in understanding the origins of our universe, as they are the oldest known objects in the Solar System"

Clues from meteorites

How these space rocks are essential in understanding the origin of Solar System


Floating through space
When a meteorite is travelling through space, it is referred to as a meteoroid. They are the oldest, and most well preserved, bodies in the Solar System.
Entering the Earth's atmosphere
When a meteoroid enters the Earth's atmosphere, it is then a meteor. If a meteor is large enough, it can survive the intense friction of Earth's atmosphere.

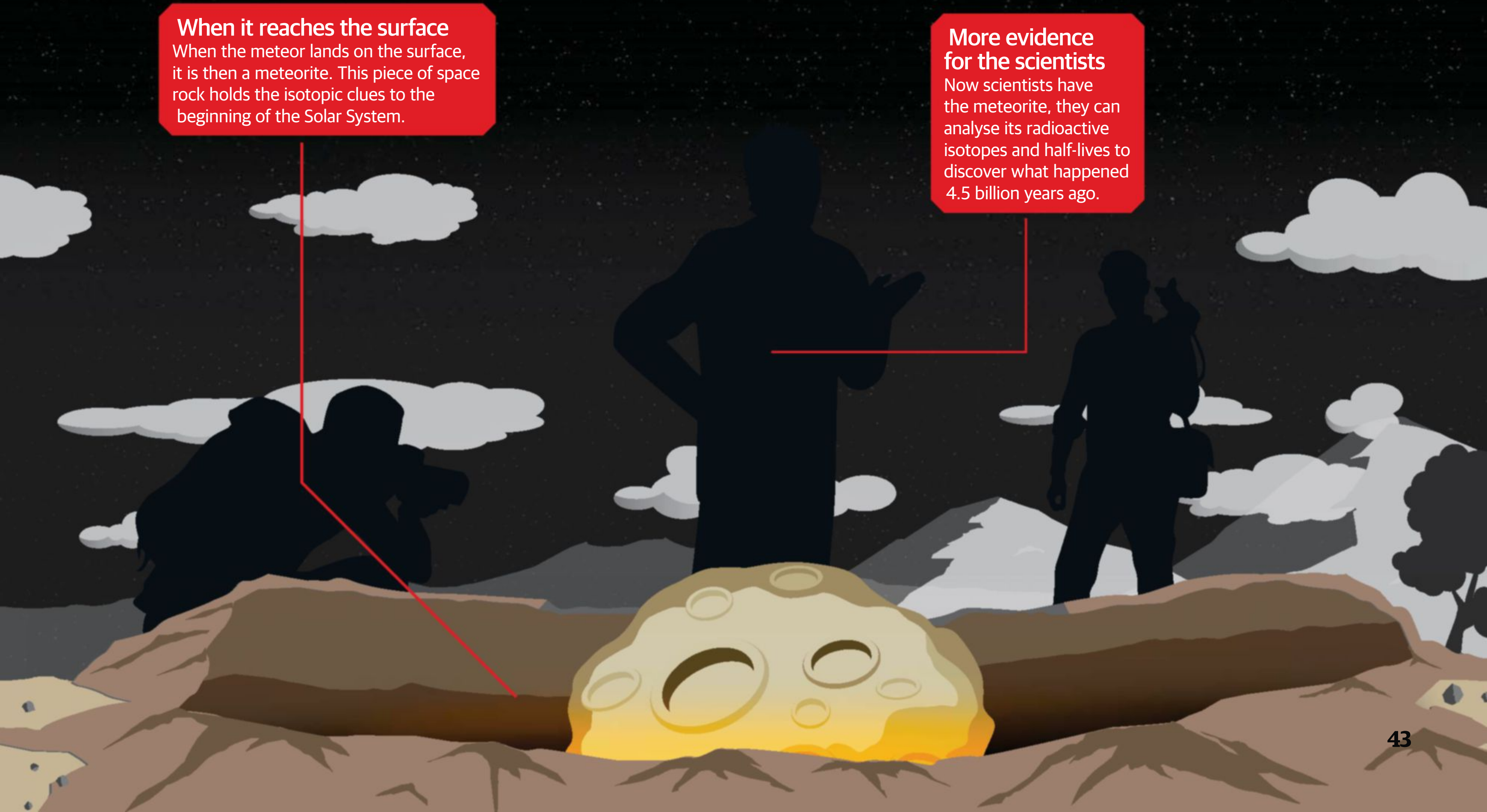
It is known throughout the universe that Iron-60 is produced in certain kinds of stars, including 'Asymptotic Giant Branch' (AGB) stars, which turn supernova later in their life. The half-life for Iron-60 is roughly 2.6 million years, which compared to the age of the Solar System is only a fraction of time. With this relatively short half-life, it is clear that all the Iron-60 has vanished from meteorites, which is why astronomers rely upon examining Nickel-60.

Dr Myriam Telus, also of Carnegie Institute of Science, analysed the isotope Nickel-60 within meteorites. Her studies confirm that the amount of Iron-60 present in the early Solar System is consistent with a supernova origin. By combining Telus' meteorite analysis with 3D hydrodynamical calculations, Boss is confident that a supernova caused the collapse of our presolar cloud. "My work has focused on determining what type of shock wave can strike a dense molecular cloud core and cause it

Meteorite recovery is a very careful procedure, as scientists need to avoid contamination

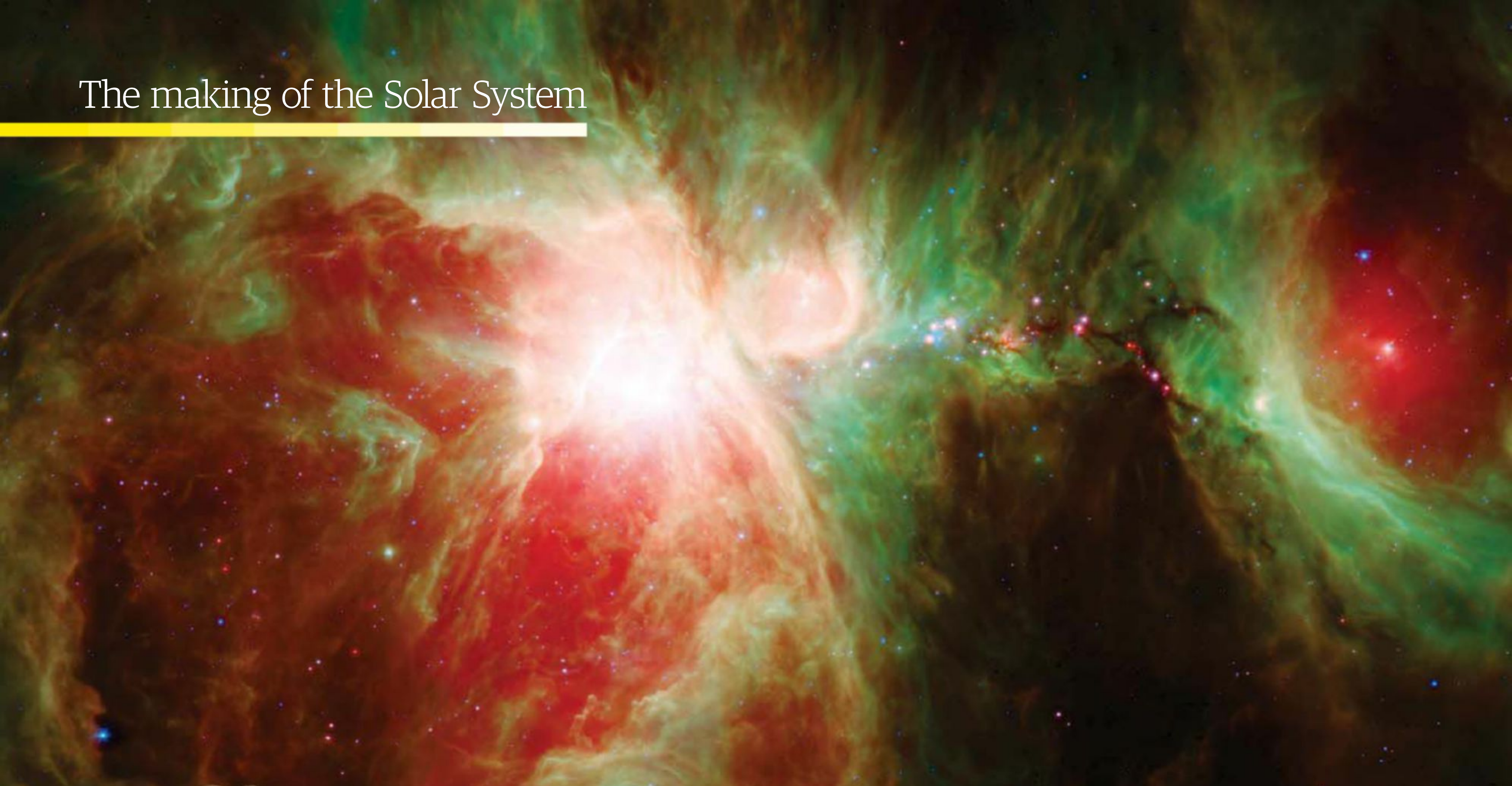
© NASA/JPL-Caltech; NASA/H. Raab

Our planets, moons and asteroids all formed from the same protoplanetary disc



When it reaches the surface
When the meteor lands on the surface, it is then a meteorite. This piece of space rock holds the isotopic clues to the beginning of the Solar System.

More evidence for the scientists
Now scientists have the meteorite, they can analyse its radioactive isotopes and half-lives to discover what happened 4.5 billion years ago.



The Orion Nebula (seen here in infrared) is a gaseous cloud home to star formation

> "My work has focused on determining what type of shock wave can strike a dense molecular cloud core and cause it to collapse" **Dr Alan Boss**

to collapse, while simultaneously injecting sufficient shock wave material to explain the meteoritical evidence," Boss tells **All About Space**. "Shock waves from massive Wolf-Rayet stars, from protostellar outflows and planetary nebula blown off by AGB stars all seem to fail to achieve both triggering and injection: so far only a supernova shock wave seems able to meet both criteria."

The work that Boss has conducted has allowed him to add some physical constraints to the pre-supernova star. Based on the isotopes produced, and ultimately integrated in our Solar System, the original star must have been between twenty and twenty-five solar masses. Not only that, but Boss has also estimated how far away this star must have been. "The supernova was probably about ten parsecs (33 light years) away from the presolar cloud. This distance is what is needed to slow down the supernova shock wave to a speed that can result in triggering and injection," he explains.

Wolf-Rayet stars are extremely massive and exhibit a drastic expulsion of stellar winds and shock waves towards the end of their life

There has also been another study along the same lines by Professor Yong-Zhong Qian and his team at the University of Minnesota. Similar to Boss' study, Qian and his team produced computer models, and then compared them to results of meteorite analysis. Qian's study differed in that they focused on low-mass supernovae (stars with masses less than twelve-times the mass of our Sun), and they investigated different isotopes that would arise from the stellar explosion. The isotope in this study is on Beryllium-10 (which contains four protons and six neutrons), as it is commonly found in meteorites. It has caused a bit of a perplexing anomaly for astronomers, as they can't seem to explain its presence. It was originally thought that this isotope was formed via spallation, a process where high-energy particles strip away protons or neutrons to form a new nucleus, by cosmic rays. In response to this, Qian argues that this theory involves too many uncertain inputs, and also presumes that Beryllium-10 cannot be produced in supernovae.

Using new models of low- and high-mass supernovae, Qian and his team showed that Beryllium-10 can be created in both of these supernovae. However, it is only low-mass supernova that could explain the vast amounts of Beryllium-10 shown in meteorite records, and even a few other elements. "The findings in this paper have opened up a whole new direction in our research," Qian said. "In addition to explaining the abundance of Beryllium-10, this low-mass supernova model would also explain the short-lived nuclei Calcium-41, Palladium-107 and a few others found in meteorites. What it cannot explain must then be attributed to other sources that require detailed study."

Unfortunately there is still so much more to be studied to provide a definitive answer. We currently have an array of puzzle pieces, but only half the puzzle is solved. The next step for Qian and his team is to uncover the outstanding mysteries of the other short-lived nuclei present in the meteorites, which includes introducing the presence of Lithium-7 and Boron-7 into the theory. Boss also emphasised the need for more meteorite evidence, unfortunately it is extremely rare for a piece of space rock to survive the Earth's atmosphere and land for study.

Until a new piece of space rock breaks through the atmosphere and crashes on the ground successfully, astronomers just have to work with what they've got. It is clear though that there is enticing, promising and intelligent work going into the subject, and scientists are becoming ever closer to finding out the true answer of how our Solar System was created.

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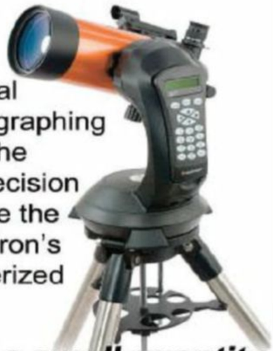

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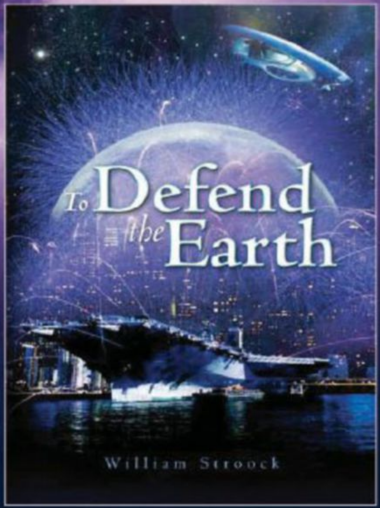

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BLAPs: The new kind of pulsating star

All About Space meets astronomer Pawel Pietrukowicz, who reveals more about an odd type of star he's found in our galaxy

Interviewed by Lee Cavendish

Can you tell us about the new discovery, and how these new stars differ from other pulsating stars?
These 'Blue Large-Amplitude Pulsators' (BLAP) that we discovered are almost half an hour pulsators [stars that have their surface periodically change size, hence changing its magnitude], so their pulsation periods are between 20 - 40 minutes, and they have exceptionally large amplitude changes. They differ from other variable stars because of the high-amplitude change in very short periods. We know that classical Cepheids, RR Lyraes and Mira stars are variable stars of much longer periods, consisting of days, weeks or even months.

If you compare these [BLAPs] to Cepheids, Cepheids extend over a larger fraction of the star's magnitude, but their periods are much shorter. If we compare this to our Sun, a typical BLAP is about 70 per cent the diameter of the Sun. However, the change in the surface is remarkably large, because more than 10 per cent, about 13 per cent, is the change in the BLAP's diameter. So if you imagine it takes only half an hour to make this change, it goes incredibly fast.

What differentiates this pulsator from others is that other pulsators are mostly red giants, which are cool stars of about 3,000 to 5,000 Kelvin. These BLAPs are variable stars that are very hot. They have temperatures of about 30,000 Kelvin, making them appear blue. Based on these observational properties, we called them Blue Large-Amplitude Pulsators, or BLAPs because that is the acronym.

You've gone into fine detail about the pulsation of the star, but what would happen to the Sun if it were to pulsate with such intensity?
The Sun pulsates of course, but the pulsations are very, very, very small. We can detect them, but not by eye. The physical mechanism behind the pulsations is different though. The Sun produces solar-like pulsations, and the pulsation in classical Cepheids, RR Lyraes and BLAPs are different. They are large-scale pulsations, which are caused by pressure waves.

What was it that made you realise you'd made a brand new discovery?
I work with the Optical Gravitational Lensing Experiment (OGLE) team. This is a really long-term experiment, as it started 25 years ago in 1992, with the prime aim of looking for dark matter. To be more specific, it was looking for microlensing events. So the idea was to solve the phenomenon of dark matter through making observations and describing microlensing events. But this was in the 1990s, and we changed to a large-scale operation since. We upgraded the camera several times at our telescope at the Las Campanas Observatory, Chile. Now we are a large-scale survey, and what we are now searching for all the time is light variability.

The Large (right) and Small (left) Magellanic Cloud do not show any signs of these BLAPs, as of yet.

©ESO/S. Brunier

The OGLE survey has observed a billion stars throughout the years, with a million of them being pulsating stars

INTERVIEW BIO

Pawel Pietrukowicz

Pietrukowicz is a Polish astronomer, who currently works for the University of Warsaw and the OGLE survey team. He received his masters from Warsaw University Observatory, and then earned his PhD at the Nicolaus Copernicus Astronomical Center, Warsaw. He spent two years at Pontificia Universidad Católica de Chile, Santiago, Chile, working as a postdoctoral researcher. In 2010 Pawel returned to Warsaw University, where he has since worked as part of the OGLE team. The project focusses on studying stars that show light variability.

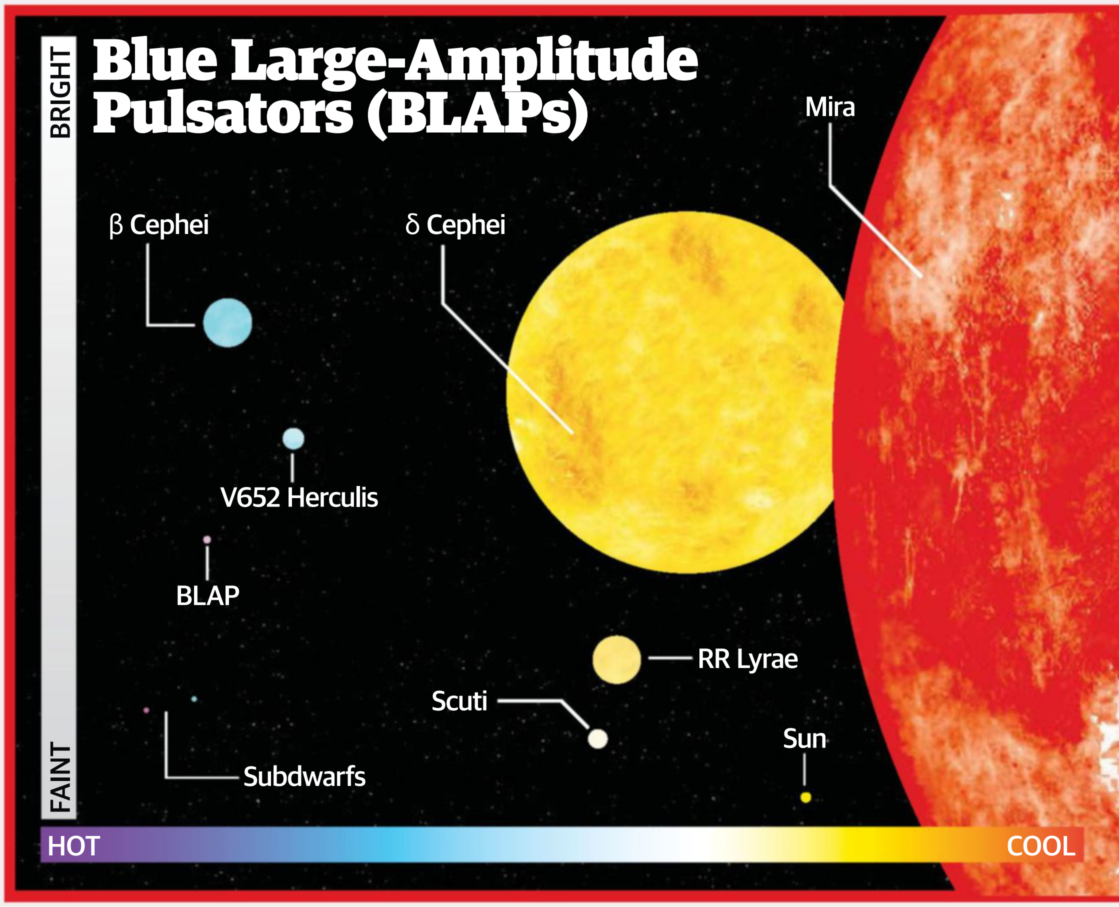
BLAPs are most likely the result of a merger of a binary star system

© NASA/C. Reed; KszuloFotki

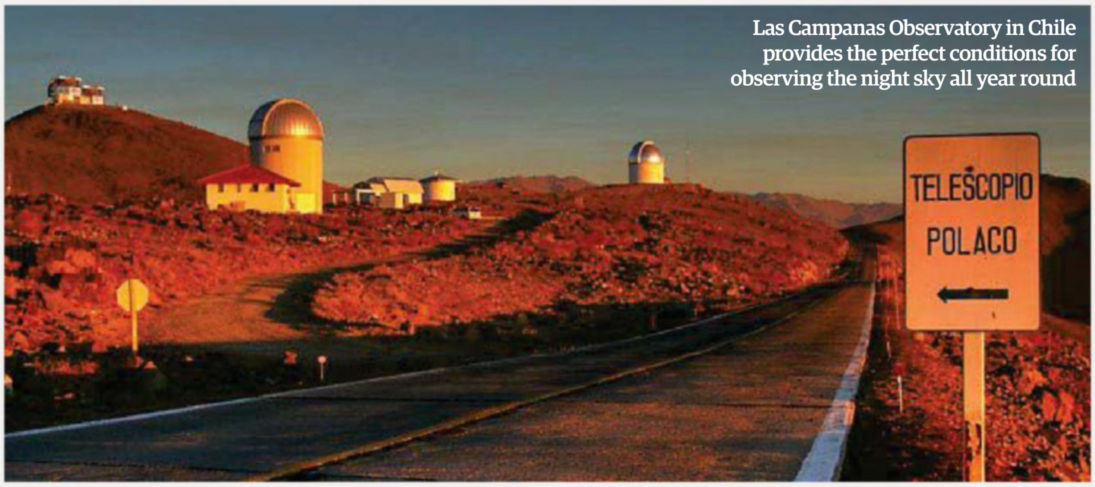
We are looking for any kind of variation in the light of stars, and we specialise in dense stellar fields in the sky, particularly the area of the galactic plane and the galactic bulge. This is where the number of stars is really huge, and where many surveys will have problems measuring the stars, because they are so close to each other. We have to handle a billion stars a night, so we measured the brightness changes of stars every night. We're looking for any kind of variation, whether it is periodic, transient or irregular, and in our collection there are 1 million variable stars. We categorise these variable stars into different groups, such as eclipsing binary stars, pulsating stars, microlensing events, erupting stars, nova and supernova events. We found almost half a million pulsating stars in the galactic plane, the galactic bulge and also the Magellanic Clouds (which are seen from the southern hemisphere). You may know that pulsating stars like Cepheids, RR Lyrae and Mira stars - long period variables - are very common in our neighbourhood, our galaxy and other galaxies. The new stars (BLAPs) are very, very rare, as we only have 14 of them out of one billion stars so far.

We are probably very lucky because we are looking at the galactic disk, where you have stars that have a higher metallicity, and more metal rich objects, which is where the BLAPs are located.

Well, the whole discovery of these stars, for me, was a fantastic adventure. It started in 2013, when we looked at a piece of the sky in the galactic disc, some 70 degrees off the galactic centre. We looked for any kind of variability, and I found something



The OGLE telescope at Las Campanas, Chile has been searching the night sky for 25 years



Las Campanas Observatory in Chile provides the perfect conditions for observing the night sky all year round

> "We took more spectroscopic observations of some of the other variables, and found that they were very similar to each other"

very strange. This was an object that resembled a classical pulsator on very short time scales. It was 28 minutes the first BLAP, at that time it was classified as a known type of variable star called a Delta Scuti star. We thought it was more-or-less OK in terms of its period, but it didn't fit into the group of Delta Scuti stars because of the large amplitude. I had to conduct more observations for the spectroscopic follow-up campaign in 2014, and I found that the subject was much hotter, around 30,000 Kelvin, which is at least three or four times hotter then Delta Scuti stars. We could tell from our spectroscopic observations that our original classification was incorrect.

Later we found similar objects in the galactic bulge, another dozen stars, very similar to each other in terms of their light curve shape, time scale and the amplitudes. We took more spectroscopic observations of some of the other variables, and found that they were very similar to each other. We found very clearly that we had a new class of variable stars.

How many people are there working on the OGLE survey with you?

About twelve. We are based at the Warsaw University, but the telescope is located at the Las Campanas Observatory in Chile. The telescope is small, with a 1.3-metre sized mirror, and if you compare it to the Magellan Telescopes or the VLT [Very Large Telescope], it is very small. The advantage is we have this telescope for the whole year, another thing is that the weather over Las Campanas is really clear. For example, in 2014, I counted the number of clear nights, and it was 330, so this is incomparable to other places. The observing conditions are really great, so for us who observe dense stellar areas – which are dense crowded areas where there are many stars – this is a perfect location. So that's why, thanks to these long-term studies, precise photometry and the billions stars out there, we were able to find these new pulsators.

How have we not discovered these brand new stars before?

I think we were lucky because of the location, and the fact that we are monitoring a huge number of stars. The fact that they are really rare is important. For example, I am currently looking for these stars in the Magellanic Clouds, the irregular galaxies, and it seems that they are absent in these clouds. They seem to only be in metal rich systems, so like our galaxy, or perhaps M31, but we don't know yet. We concentrate on the galactic strip, the galactic bulge, the galactic centre area and the galactic disc, and there you have stars that are more metal rich.

Astronomers use variable stars, such as Cepheid stars, to measure cosmic distances. Do you think these BLAPs could be used as a distance-measuring star?

I think so, but the problem is the amount of stars there are, as the number of observable BLAPs is very small. If you want to measure the distance to a local galaxy, then you have to find at least one BLAP – or even more – to have more precise information on the distance. I think these stars may be used, but the problem is the amount.

I think these stars will be better used to study stellar interiors and their formation. This is because they are untypical: they are not like our star, other main sequence stars or even classical red giant stars. They are most like subdwarfs, and we think that subdwarfs are the result of mergers. For example, some subdwarfs are single stars, and they are believed to be the result of a merger of a binary of white dwarfs. So this makes us think that BLAPs are the result of mergers, because I don't see any companions to these stars in our data.

We did have this idea that they [BLAPs] were formed in a different way, because the problem with subdwarfs and BLAPs is that they must have lost a lot of mass. This loss is close to 75 per cent of the original mass, which is impossible in the evolution of a single star. Our Sun cannot lose 70 per cent of its mass, as it's impossible, unless it passes close by an object with a large gravitational force, like a black hole.

Our idea was maybe BLAPs were originally single stars that passed by the supermassive black hole at the centre of our galaxy. However, the problem with this scenario is that we expect the star to be travelling at a high velocity, as it should have been ejected from the black hole at a high velocity. Though from our spectra, it doesn't fit to this idea, because there is no shift in the lines of the spectra. So for objects that are in a 'runaway' scenario, we expect them to have extremely high velocities because they are escaping from the Milky Way, but BLAPs are clearly single stars with low galactic velocities, so this close encounter scenario is probably incorrect. At this point, we think it is most likely that these are the results of mergers.

Is there more to be done on understanding them?

Well, we don't know what the masses of these stars are, and this is an important question at the moment. From our data, our models and our investigations, it seems there are two options: they may be either 0.3 solar masses or one solar mass, and both of these options seem to be possible right now.

Of course, measuring mass in astronomy is really difficult. The best way to measure the mass of an object is to find an eclipsing companion. In the case of a single object it is really difficult, and the accuracy is really bad. We would like to know the mass of the object, and this is impossible with photometry, so I would like to measure the mass with spectroscopy and fit a better model to newer data.

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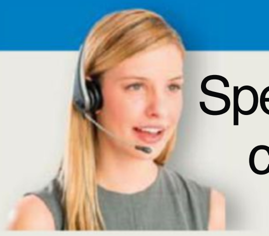

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JOURNEY TO THE CENTRE ICE GI

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At the far reaches of the Solar System, two worlds remain a mystery to us – but recent research could have given us a peek into the unknown

Written by Kulvinder Singh Chadha

Uranus and Neptune could be stranger than we once thought. On the surface these two planets – roughly mid-way in size between Earth and Jupiter – seem unassuming, if different from one another. Uranus being a featureless, pale-azure planet, and Neptune a deep-blue one, with white cloud bands and a dark storm system similar to Jupiter's Great Red Spot. But at heart they may be much more alike, as well as unlike anything we would encounter on Earth. Latest studies are showing that in terms of chemistry, density, temperature and pressure, the interior of these worlds has the complexity of a Shakespearean character – even that they may have literal diamond rain.

Although NASA's Voyager 2 visited both planets in 1986 (Uranus) and 1989 (Neptune) – and sent back a wealth of images and data – no spacecraft has been to either world since. That may be due to the fact that Uranus and Neptune are the last two official planets, lying at the planetary edges of our Solar System 2.88 billion and 4.50 billion kilometres (1.79 and 2.8 billion miles) from the Sun, respectively. Much of our information, and all of our up-close images of these worlds, come from Voyager 2 (although both are studied by ground and space-based telescopes).

The giant planets formed in the outer Solar System where hydrogen and helium were more abundant. Clearly Uranus and Neptune aren't small and rocky like planets of the inner Solar System.

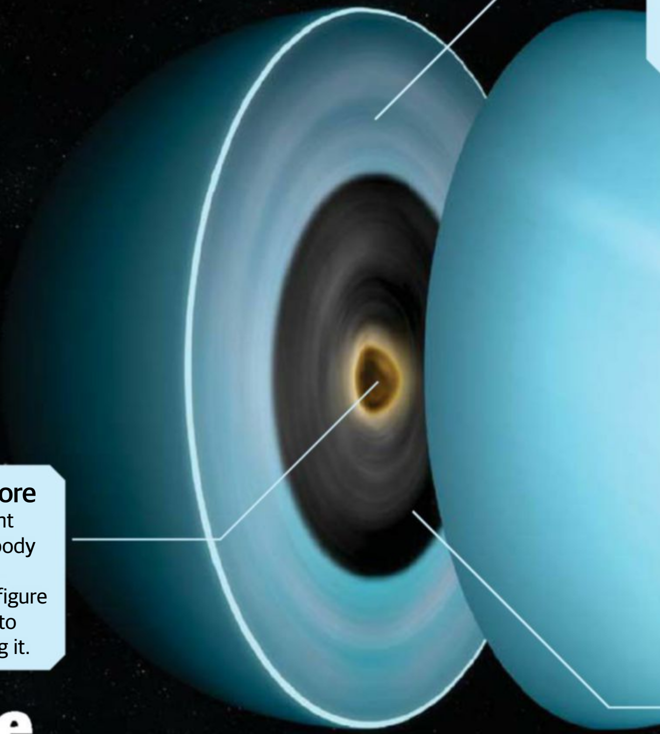
© Tobias Roetsch

Inside a frozen planet

Uranus and Neptune are thought to be composed of a core, mantle and atmosphere

Uranus

Hydrogen	82.5%
Helium	15.2%
Methane	2.3%



Hydrogen-helium atmosphere
Although by percentage the atmospheric composition of hydrogen and helium is similar to the other giant planets, by mass it's very low. There are also trace amounts of methane and other volatiles.

Silicate iron-nickel core
The Uranian core is thought to be a rocky, iron-nickel body between 0.5 to 3.7 times Earth's mass. The precise figure is currently unknown due to the difficulty of calculating it.

Fluid icy mantle
The mantle (made of ices such as ammonia, water and methane) comprises the bulk of Uranus' mass and increases in temperature and pressure towards the core. Recent studies suggest the presence of theoretical, superionic compounds.

Major moons

Diameter in miles

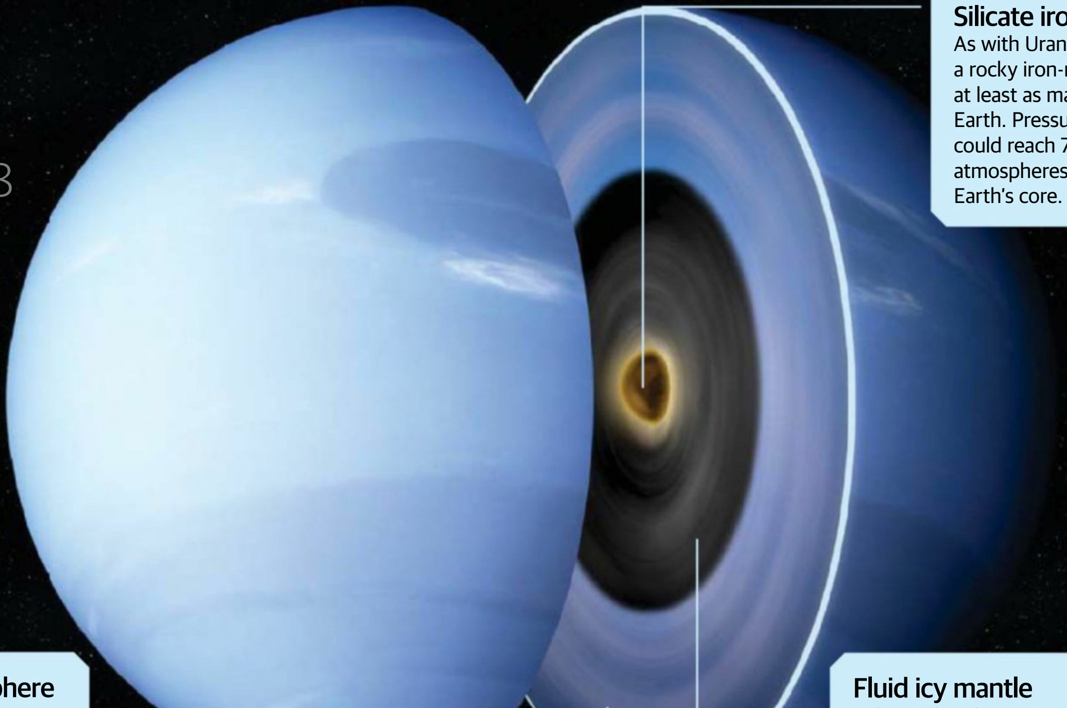
Miranda	293
Ariel	720
Umbriel	727
Titania	981
Oberon	946

Neptune

Major moons

Diameter in miles

Triton	1678
Nereid	211
Naiad	36
Thalassa	49
Despina	92



Silicate iron-nickel core
As with Uranus, Neptune has a rocky iron-nickel core that's at least as massive as planet Earth. Pressures at the centre could reach 7 million Earth atmospheres – higher than Earth's core.

Hydrogen	80%
Helium	19%
Methane	1%

Hydrogen-helium atmosphere
Like Uranus, Neptune has a hydrogen-helium atmosphere, albeit with a more dynamic climate, and prominent upper clouds. As of yet, the nature of the deep-blue colour is unknown.

Fluid icy mantle
Being an ice giant, Neptune's bulk mass is composed of a mantle made of ammonia, water, methane and other ices. Recent experiments suggest a carbon ocean and diamond rain in the depths.

© NASA; Tobias Roetsch

Neptune (pictured) is deeper in colour and displays more prominent features than its fellow ice giant, Uranus

Voyager 2 is thus far the only spacecraft to have visited the ice-giant planets

But nor do they quite reach the status of 'gas giant' like Jupiter and Saturn, even though they have similar bulk compositions of hydrogen and helium, by percentage. They belong to a class of their own: so-called 'ice giants'. The 'ice' refers to some of the volatile chemicals found – mostly – deep within. One scientist, Professor Jonathan Fortney of the University of California, Santa Cruz says, "Uranus and Neptune are generally thought of as 'failed' versions of Jupiter and Saturn. They did not accrete tens to hundreds of Earth masses of hydrogen and helium, probably because there was less gas farther from the Sun by the time they formed." Fortney is a member of the science team for a proposed future mission to the ice giants, lead by NASA's Jet Propulsion Laboratory, the Goddard Space Flight Center, and the European Space Agency.

> "Uranus and Neptune are generally thought of as 'failed' versions of Jupiter and Saturn"
>
> **Professor Jonathan Fortney**

Hydrogen and helium would also have evaporated close to the Sun once it started shining. This volatility also applies to the ices, which include ammonia, water, and methane compounds. Water might seem like a surprising addition, but it's liquid on Earth because of the pressure of our atmosphere, if you discount temperature variations.

The current, broad consensus by planetary scientists is that both planets have rocky, iron-nickel Mars to Earth-sized cores, fluid, icy mantles that are ten to 15 times Earth's mass (Uranus's calculated to be 13.4 times), and hydrogen-helium atmospheres with small amounts of methane. But even with the Voyager 2 data, scientists still don't really know what these worlds are like inside. Work done over the years almost always has to rely on computer simulations, because the planets' internal conditions are so difficult to recreate with current laboratory equipment. Ices comprise the bulk mass of the ice giants' mantles, and their temperatures and pressures change at different altitudes. This is where the term 'ices' becomes weird in the conventional sense, because the ammonia, water and methane mixtures can reach thousands of degrees Celsius in temperature the further you go down. The reason they maintain their composition is because of soul-crushing pressures of hundreds of thousands to even millions of Earth atmospheres.

A recent study has investigated this further. An international team lead by Dr Andreas Hermann of Edinburgh University's School of Physics and Astronomy and the Centre for Science at Extreme Conditions, simulated water and ammonia mixtures at low temperature conditions. They found that the mixture allowed a compound called ammonia hemihydrate to remain stable as it went through ionic 'phases' at increasingly high pressures. "There is an interesting state of matter (called superionic) where due to heat, protons become diffuse, while the heavy atoms of carbon, nitrogen and oxygen remain in a fixed lattice," says Hermann. "It's a partially molten state, that still carries signatures from the underlying crystal structures."

What this means is that molecules of superionic matter start off as a 'sea' of free-floating ions of their original selves, but then, under increasing pressure, they crystalise to become a strange liquid/solid. No superionic matter has ever actually been observed, but it is thought to exist inside giant planets. In their paper the team say that ammonia hemihydrate will likely precipitate out of ammonia-water mixtures at a high enough pressures. The reason this study is particularly important is because this result emerged from modelling a mixture of ices, instead of individual compounds, which has been the case for studies in the past.

What else did the team's study show? Hermann says, "We calculated that ammonia hemihydrate

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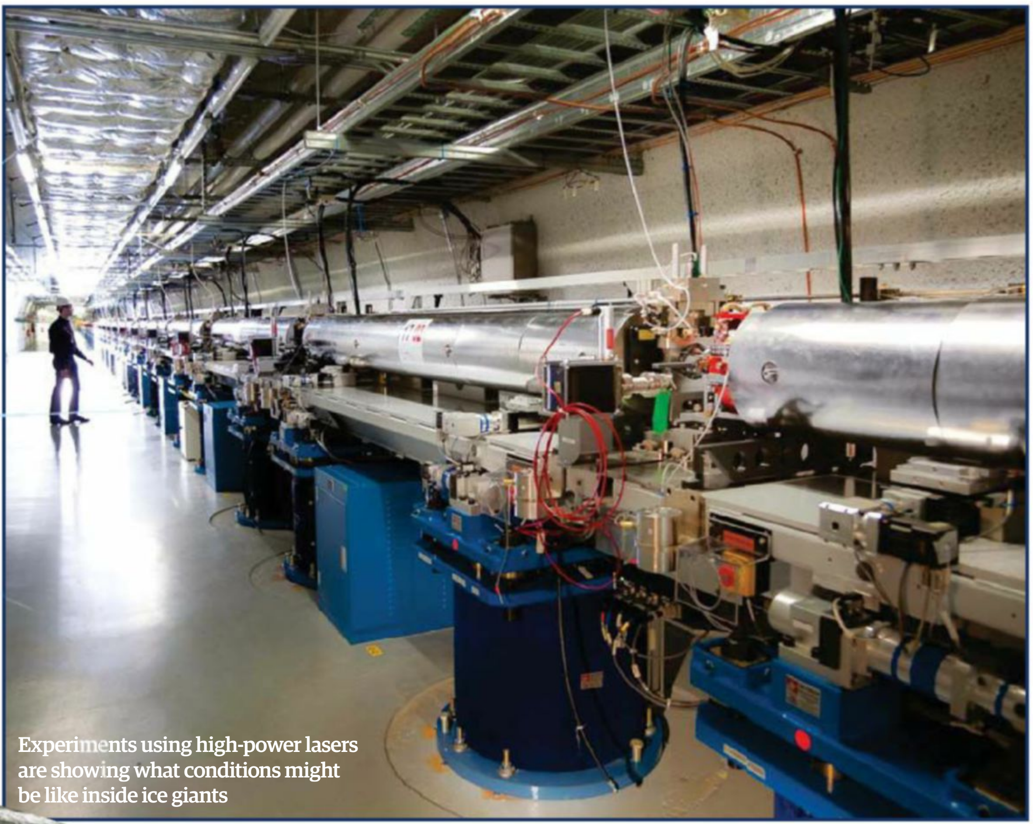


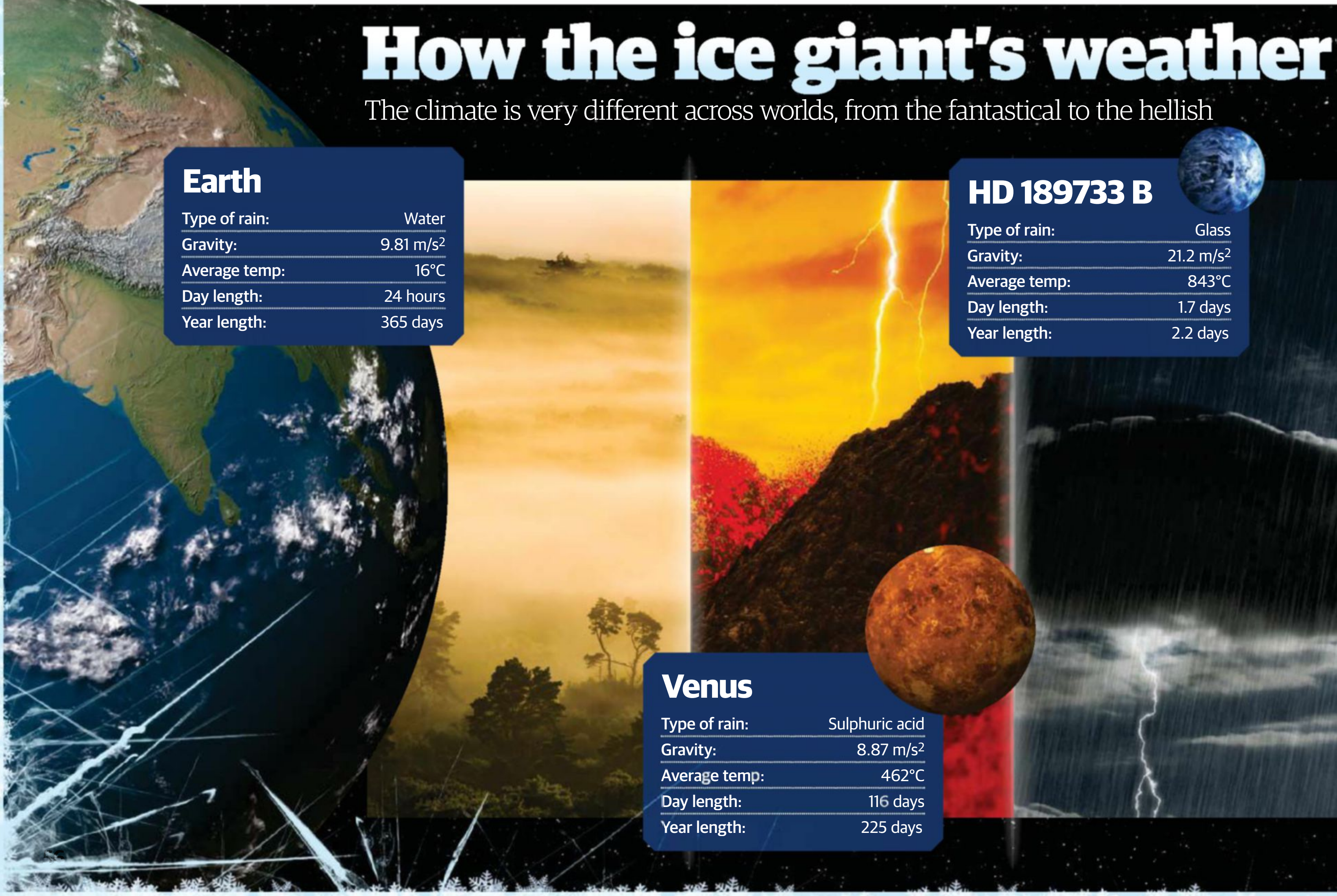
Experiments using high-power lasers are showing what conditions might be like inside ice giants

has a lower density than pure-water ice at the same pressure. It would then form a well-defined layer above an icy sea." Imagine a solid/liquid (superionic) ammonia layer above a slushy, frozen ocean, at 3 million Earth atmospheres. However, he also says that truly understanding what layers would actually form (if any) would also require adding methane and excess hydrogen to the simulations. In the meantime, the team are working on simulations of superionic ammonia hemihydrate.

Although physically recreating the interiors of the ice giants may be challenging, it's not completely impossible, as someone else has discovered. An international team led by Dr Dominik Kraus of Helmholt-Zentrum Dresden-Rossendorf, University of California, Berkley, and the Institute of Solid State and Materials Physics, fired a powerful X-ray laser at pieces of polystyrene at the SLAC National Accelerator Laboratory. The polystyrene was meant to be a stand-in for methane inside ice-giant mantles (both made of carbon and hydrogen) and the laser created two shock waves within it. Under those conditions, the shock waves overlapped and created pressures of 1.5 million atmospheres and temperatures of 5,000 degrees Kelvin for fractions of a second – briefly mimicking the conditions inside an ice-giant mantle. The team were surprised to discover that diamond was created (albeit nanometres in size). They theorise that in the more sustained conditions

How the ice giant's weather

The climate is very different across worlds, from the fantastical to the hellish



Earth

Type of rain:	Water
Gravity:	9.81 m/s^2
Average temp:	16°C
Day length:	24 hours
Year length:	365 days

HD 189733 B

Type of rain:	Glass
Gravity:	21.2 m/s^2
Average temp:	843°C
Day length:	1.7 days
Year length:	2.2 days

Venus

Type of rain:	Sulphuric acid
Gravity:	8.87 m/s^2
Average temp:	462°C
Day length:	116 days
Year length:	225 days

> “The deep cores of Jupiter and Saturn may actually resemble Uranus and Neptune, but at much higher pressures” **Professor Johnathan Fortney**

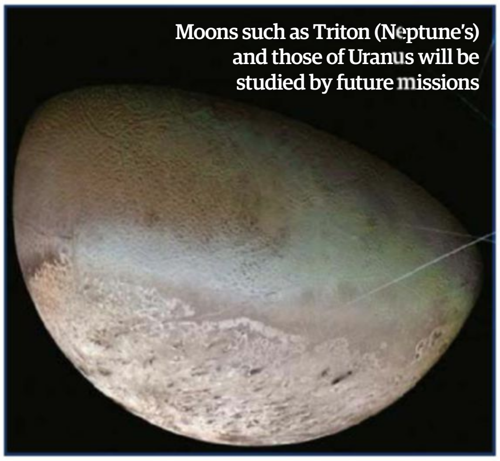
of an ice-giant mantle – around 10,000 kilometres down – the diamonds will grow to a larger size as the methane breaks down into hydrogen and carbon, and precipitate down to the core.

Previous teams have used methane inside laboratory diamond anvil cells to create diamond, but under lower temperatures and pressures. The results were always inconclusive. In another study, Lawrence Livermore National Laboratory (LLNL) scientists subjected a diamond to 1.1 million Kelvin and 40 million atmospheres to recreate the conditions inside giant planets. Their results suggested that at the bottom of the ice giant’s mantles could lie a liquid carbon layer with chunks of floating diamond. LLNL were also involved with this latest work.

Kraus’ team are now working on follow-up experiments. “Our efforts have now turned to looking at what happens when we reduce the carbon concentration in our samples and add other light elements that are also present inside Neptune and Uranus, such as oxygen or nitrogen,” he says. They’re also figuring out ways to safely capture the nanodiamond particles – which travel at incredibly high speeds, and are currently only detected via spectroscopy.

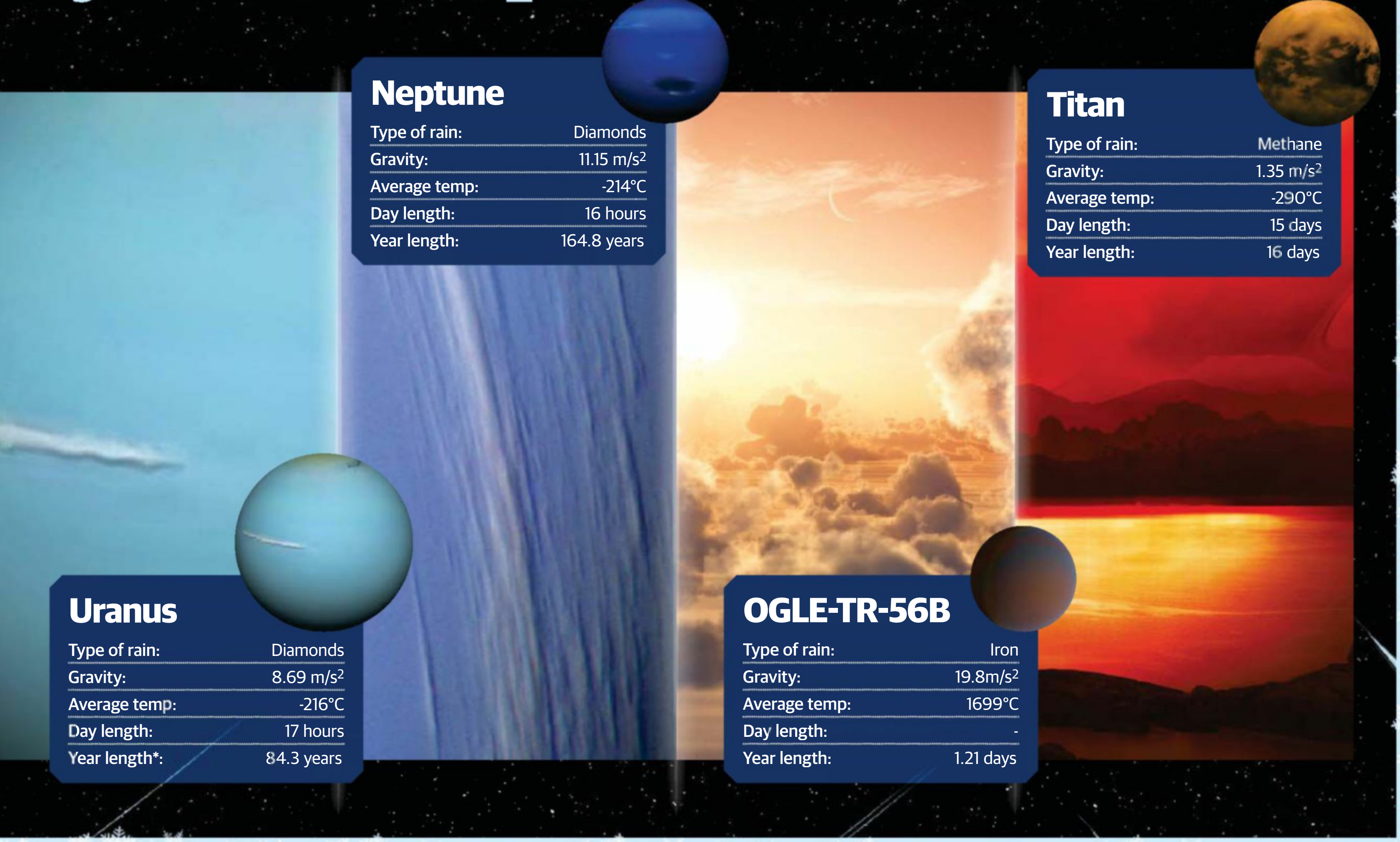
The work done may help to solve another mystery: why Uranus radiates less excess heat than it receives from the Sun compared to all the other giant planets. Even Neptune, which is further from the Sun, radiates 2.6-times as much heat as it receives. This heat energy may be what drives Neptune’s storm systems and gives it a more dynamic climate than Uranus. It’s been suggested that somewhere inside Uranus is a thermal boundary layer (in effect, planetary ‘long johns’) that stop heat from escaping. Hermann says that if the planet’s layers are more stratified than thought, “it’s not inconceivable that ammonia hemihydrate, or similar strongly bound ionic phases, could form such a layer.”

Such work could ultimately help in understanding not only the ice giants, but all the giant planets. As Fortney says, “The deep cores of Jupiter and Saturn may actually resemble Uranus and Neptune, but at much higher pressures and temperatures.”


Moons such as Triton (Neptune’s) and those of Uranus will be studied by future missions

Uranus’s azure-blue colour is caused by the presence of methane in its atmosphere

systems compare with other worlds



Neptune

Type of rain:	Diamonds
Gravity:	11.15 m/s^2
Average temp:	-214°C
Day length:	16 hours
Year length:	164.8 years

Titan

Type of rain:	Methane
Gravity:	1.35 m/s^2
Average temp:	-290°C
Day length:	15 days
Year length:	16 days

Uranus

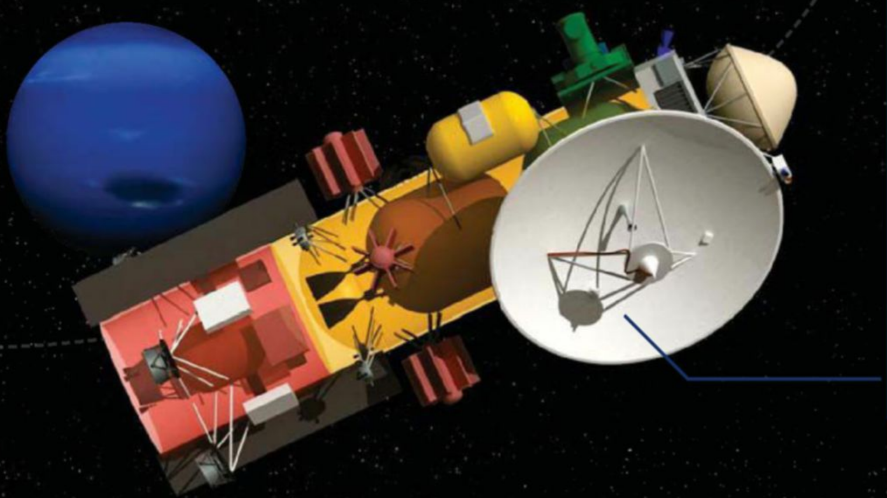
Type of rain:	Diamonds
Gravity:	8.69 m/s^2
Average temp:	-216°C
Day length:	17 hours
Year length*:	84.3 years

OGLE-TR-56B

Type of rain:	Iron
Gravity:	19.8m/s^2
Average temp:	1699°C
Day length:	-
Year length:	1.21 days

Missions to Uranus and Neptune

NASA's Pre-Decadal Survey Mission Study Report suggests several possible future spacecraft to the ice giants



Neptune orbiter with probe

Launch date: 2030

Operator : NASA-JPL, ESA, Aerospace Corporation

Mission length: 15 years

A minimum 50 kilogram science payload would be required for a mission to Neptune. This would include both the orbiter and probe's science packages. The orbiter would study Neptune's moons – particularly Triton – which is a captured Kuiper Belt Object. It would also study Neptune's weather systems, magnetosphere and solar wind particles at this distance. The atmospheric probe would be required to accurately measure the abundance of noble gases (including hydrogen and helium) and other elements. The probe would need a mass spectrometer and instruments to measure pressure, density and temperature. The orbiter would need a magnetometer and a camera.

Uranus orbiter only

Launch date: 2031

Operator : NASA-JPL, ESA, Aerospace Corporation

Mission length: 15 years

An orbiter-only mission would weigh three-times as much as the other mission concepts, but carry five-times as many instruments. Alongside the narrow-angle camera and instruments for measuring magnetic fields and interior atmospheric structure, the Uranus orbiter will have spectrometers, a dust detector and other devices. It would also have a wide-angle camera for snapping wide vistas of the planet, its moons, and its rings. As well as achieving the other orbiter goals, it may clear up other, long-standing ones. One big mystery of Uranus is why it radiates so little heat compared to the other giant planets.

Uranus flyby with probe

Launch date: 2030

Operator : NASA-JPL, ESA, Aerospace Corporation

Mission length: 10 years

A flyby mission to Uranus, weight for weight, would be the cheapest ice-giant mission option, and it would achieve many of the same science objectives. However, a flyby mission wouldn't have much time to study the planet, its moons or ring system. It would have to work fast and release its probe. As with Neptune, the probe would be required to measure the abundance of hydrogen, helium, heavier noble gases and other elements (such as volatiles) in the atmosphere. Although not the same as Neptune, a lot could be inferred from it by studying Uranus.

Uranus orbiter with probe

Launch date: 2031

Operator : NASA-JPL, ESA, Aerospace Corporation

Mission length: 15 years

A Uranus orbiter with a probe would have a major advantage over a flyby mission. While the probe studied the planet's atmospheric layers, the orbiter could study the moons and ring system in great detail and make new discoveries. As a comparison with the Cassini orbiter to Saturn, unexpected discoveries (such as plumes of water ice on Enceladus) were a fortunate consequence. A Uranus orbiter-probe mission would be almost the same as the Neptune orbiter-probe concept. It's thought that both planets' moons harbour water in some form. That means this would be of value in understanding both planets' environments.

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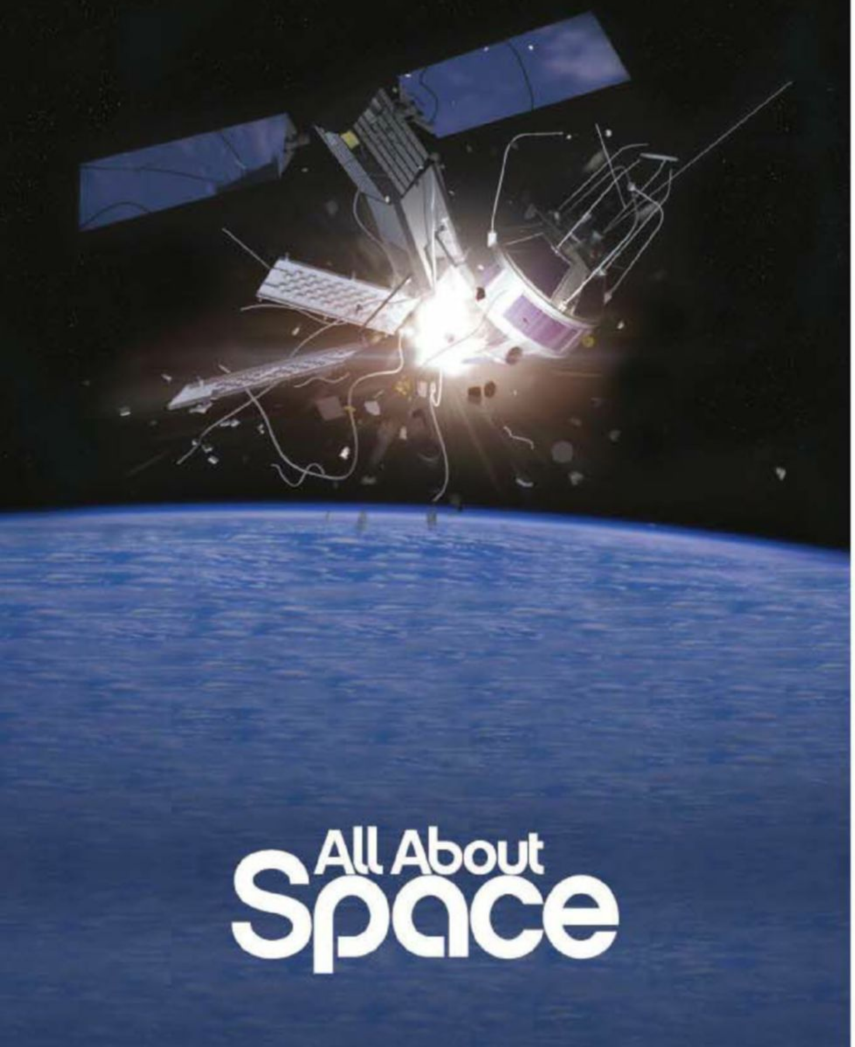

All About Space

Haynes

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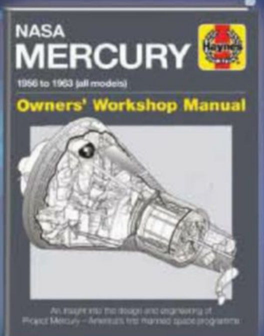

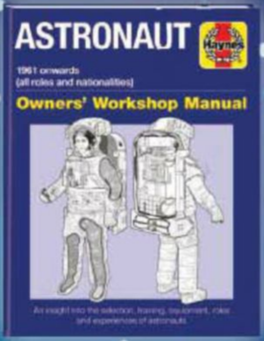

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Observing the starry sky

If we find ourselves under a particularly dark sky, hardly any of us can resist looking upwards and admiring the fascinating 'starscape' revealed.
But what would it be like if we could observe entire constellations, see many more stars and even numerous other objects? Almost as if we could 'zoom in' with our eyes? Then we would probably have super-hero eyes, or alternatively we could simply use these 2.1×42 binoculars for observing starfields.

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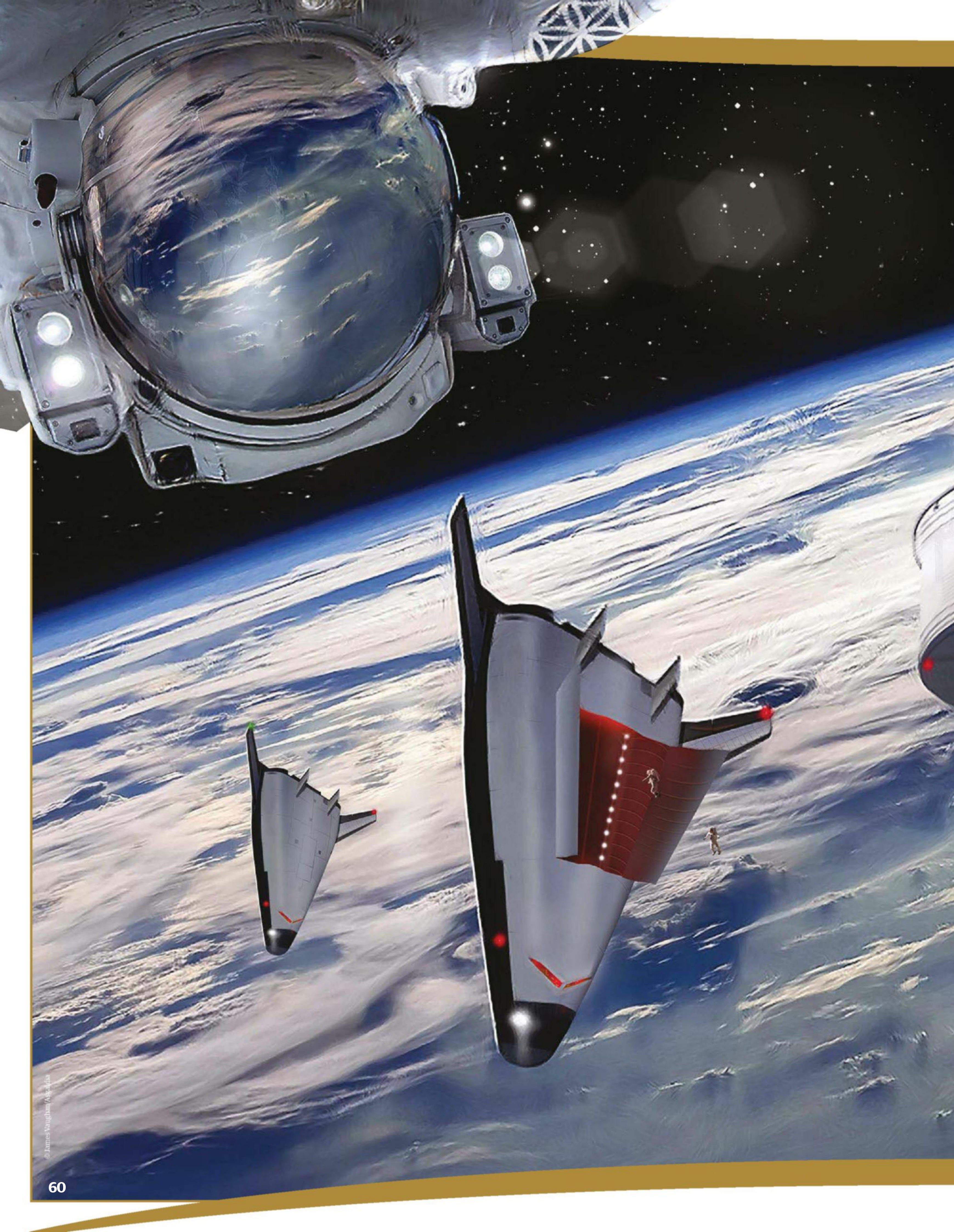
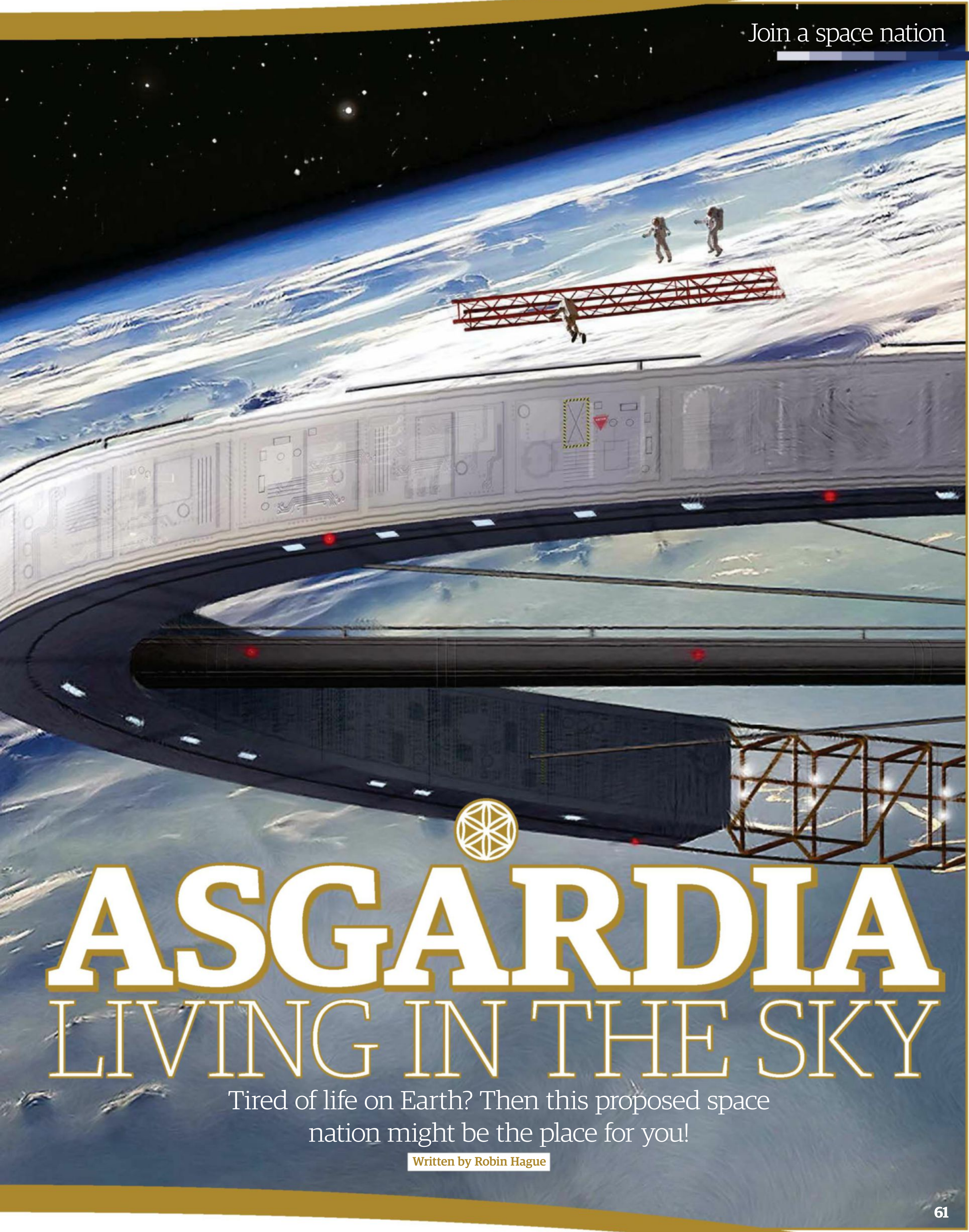


© James Vaughan/Asgardia



ASGARDIA

LIVING IN THE SKY

Tired of life on Earth? Then this proposed space nation might be the place for you!

Written by Robin Hague

Asgardia founder, Russian scientist and entrepreneur, Igor Ashurbeyli

Among the selection of would-be countries around the world, Russian scientist and entrepreneur Dr Igor Ashurbeyli is offering something new: he wants to create a new nation around the world, in every direction. He has started a project to create a new nation, officially organised, governed and accepted into the United Nations - but in space. Fearful of historic Earthly animosities spreading into space, and the rewards and resources of the Solar System being claimed by only the wealthy nations, he launched Asgardia, named for one of the residences of the Norse gods, in 2016.

At present, the United Nations Outer Space Treaty makes the space activities of individuals and organisations the responsibility of whichever their home nation is, and specifies that nations of the Earth cannot own territory in space. However, these conventions were established in the context of escalating cold war tensions, and when access to space was the preserve of the superpowers rather than private enterprise. With Asgardia, Ashurbeyli hopes to establish a new and open legal framework for space, built around the new nation.

While the idea of a space nation brings to mind the giant rotating space stations and Moon bases of science fiction, the Asgardia project is already collecting an interested population, and plans to apply to the United Nations long before they reach that stage. Actual space settlements are their goal, but one worked towards in small steps, both legal and practical, and 2017 has seen both.

The first step to the formal establishment of Asgardia as a real nation has been the creation and online acceptance of a constitution by more than 100,000 people. Those wishing to take up citizenship (which of course Asgardia accepts is in parallel with your existing Earthly nation) need only click a button to accept the constitution to become a citizen. As described by Ashurbeyli, "Physically the citizens of that nation state will be on Earth. They will be living in different countries on Earth, so they will be a citizen of their own country and at the same time they will be citizens of Asgardia." The first 100,000 citizens (they've now reached 111,112) will get to send a 500kb data package, text or pictures, into space on Asgardia's first satellite. Asgardia 1 is a cubesat that is being produced by Nanoracks, a company from Texas

"They will be a citizen of their own country and at the same time they will be citizens of Asgardia" **Igor Ashurbeyli**

Bigelow Aerospace is developing off-the-shelf space stations that could be the start of independent Asgardia

Asgardia: your space nation

Asgardia 1

Asgardia's first 'territory' in space will be the Asgardia 1 nanosat, to be launched in November 2017. It will carry a database of citizen's data. Ashurbeyli's initial plan is to create Asgardia as a virtual nation; citizens around the world linked by a common concept and online community.

Founder

After starting a software development company in 1988, Dr Igor Ashurbeyli has been involved in many areas of computing, telecommunications and aerospace.

A growing population

Starting in early 2017 the Asgardian constitution was placed online for voting. Anyone wishing to join the nation simply has to read through the constitution and click to accept. The initial target was to reach 100,000 citizens by this means to demonstrate credibility.

United Nations recognition

This is unknown legal territory: Ashurbeyli has compared the process to how Israel built up to international recognition, but no one has secured nation status for an organisation without land.

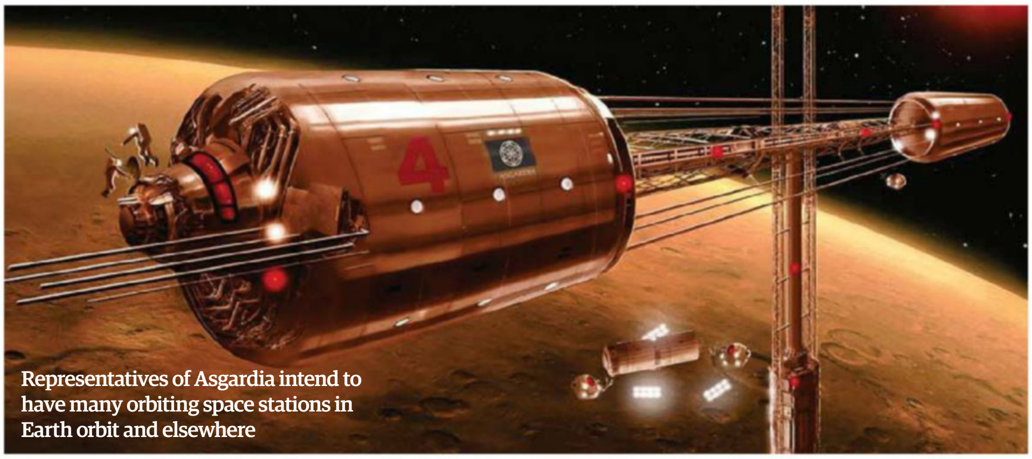
Earth's back-up

A key inspiration for Asgardia, like Elon Musk's Mars plans, is to remove humanities sole dependence on Earth. They hope to protect Earth from space-based threats and environmental threats, by developing in-space capabilities and living spaces.

Documents

Ashurbeyli hopes to have a functioning administration created during 2018, following the first parliamentary elections in the autumn of 2017. Once that is in place Asgardian documents, real passports, birth certificates and such, will be available.

© James Vaughan/Asgardia; Linda Yeleussizova; NASA/Bill Ingalls



Representatives of Asgardia intend to have many orbiting space stations in Earth orbit and elsewhere

who have a system to deploy satellites from the International Space Station (ISS), and its service ships. Asgardia's satellite will be launched in November on an Orbital ATK Cygnus ISS cargo ship. After a couple of months docked to the ISS the Cygnus will separate and boost Asgardia 1 (and other Nanoracks payloads) out into higher orbits. The idea is to found Asgardia first as a virtual nation online, and in the citizen's data placed aboard the satellite.

After the constitution, next in the plan is to establish a working government, elections should be completed by the end of 2017 for a parliament, and a network of distributed representatives established around the world in the hope of organising local Asgardian events. Then they intend to form ministries for various causes, presumably drawn from the parliament and subject experts. There are already plans for a central bank, with the Asgardian Solar as an independent currency, and the intent is to provide Asgardian passports and birth certificates to citizens who would like them. Somewhat unexpectedly given Ashurbeyli's focus on open, global equality Asgardia is styled 'The Space Kingdom of Asgardia'. Although Ashurbeyli is leading and funding the whole project so far, he's not the king, though he is 'Head of State', but he will step down in five years when he hopes to hold an election for a replacement. He has copied the constitutional monarchy pattern after stable, liberal monarchies like those of the UK, The Netherlands and Scandinavia.

Rules of Asgardia

It's intended to be a free and unified space nation

- The objectives of Asgardia are to ensure permanent peace in space, to ensure equal opportunities in space for all Asgardians currently residing on Earth, regardless of their Earthly citizenship and to promote the welfare of the entire humankind.
- Anyone can become a citizen of Asgardia, conditional on assenting to the declaration and abiding by the constitution and the legislation of Asgardia.
- All citizens of Asgardia are equal, irrespective of their Earthly country of origin, residence, citizenship, race, nationality, gender, religion, language, financial standing or any other attribute.
- Asgardia respects the laws and international treaties concluded by the Earth's States, and wishes to be recognised as having equal status as the Earth's States.
- Asgardia does not interfere in any affairs of the Earth's States based on reciprocity.
- Asgardia participates in the global events on Earth, similar to the Earth's States, based on its membership in the respective international organisations.
- Asgardia respects, complies with, and protects the rights of citizens of the Earth's States and protects Asgardia's citizens in the exceptional nature of their space citizenship.
- Asgardia has no place for political parties, but every Asgardian can freely participate in the political life on Earth.
- Asgardia mirrors the Earth without reflecting Earthly borders. Nevertheless, in the framework of Earthly laws, every Asgardian can freely live within the borders of any Earth State.
- Asgardia is a nation of free spirit, science and internationalism. Every Asgardian can freely practice any religion of Earth in Asgardia.
- There is no place for the history of Earthly conflicts in Asgardia. Asgardia creates a new, peaceful history of the future space humankind.

Individuals who sign up to be an Asgardian are also a citizen of their own country on Earth

Once Asgardia has a population, a governmental system and functions together as an ongoing whole, then they will apply to join the United Nations as an actual country; even though their territory will be online, and their population shared with other nations. But what about what we really want from something so fancifully named 'Space Kingdom'? Plans for actual space settlement!

Well Asgardia 1 is intended to be just the first of a growing constellation of satellites, expanding Asgardia's digital territory in space. These would also presumably provide a means of generating income for Asgardia, via secondary satellite services, to help fund the next stages of development. Ashurbeyli believes the first Asgardian astronauts will take flight within eight years, and this has never had a better chance of happening than now. Bigelow Aerospace has been developing huge inflatable space stations since 1998, waiting for commercial space travel vehicles to permit access. SpaceX and Boeing are shortly to launch new crew carrying capsules, which could be used beyond the NASA contracts that covered their development, or launch free flying science missions as SpaceX have proposed with their Dragon capsule. Sierra Nevada is making good progress on their Dream Chaser lifting-body space plane, especially now they are signed up to deliver cargo for NASA. They're also in discussions with the United Nations to provide space flight opportunities for poorer countries that would not otherwise be able to afford science on such a scale; which is also one of Asgardia's three key aims. So it will shortly be possible for any organisation to purchase the complete set of hardware and transport necessary to establish a space station, or even an interplanetary mission.

Looking ahead, Asgardia plan to have multiple space stations in Earth orbit and elsewhere, creating real physical territory for the prospective nation. They have even been considering what they have referred to as 'Space Arks' - settlements in space to back-up the Human Race against disaster on Earth, as Elon Musk has described for Mars. But Asgardia plans to go even further, with their second key aim to protect Earth against threats from space. As well as the usual asteroidal and cometary impacts, they have identified five other existential threats that Asgardia could help mitigate. Coronal mass ejections from the Sun, a failure of the Earth's magnetosphere,

> "Asgardia plan to have multiple space stations in Earth orbit and elsewhere"

Sierra Nevada's Dream Chaser is part of the new generation of potential space taxis

© James Vaughan/Asgardia; Jason Hayes; Patrick Gruban

Voting in Asgardia

Acceptance of the constitution
Accepting the community-based constitution is the basis for taking up citizenship, over 100,000 people have done this in less than a year.

✓

Regional representatives selected around the world
Asgardia hope to have a network of local representatives, to become one you need to collect signatures from citizens.

✓

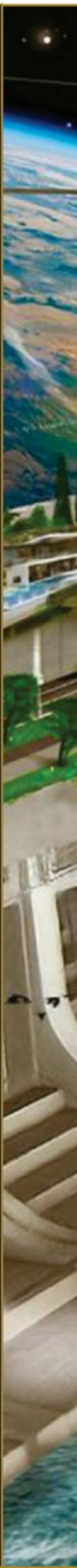
Stages of status
With 10 votes you can be a 'débutante', 100 votes a 'strategist', 1,000 votes a 'trendsetter' and 10,000 votes a full Asgardian Ambassador.

✓

Parliament
The global representatives aren't the Asgardian MPs, they will be separately voted for in elections towards the end of 2017.

✓

Head of state
Igor Ashurbeyli is the first head of state, but he intends to step down in 2022, and then elections are expected for a new head.



human-made orbital debris, climate change, radiation from supernovae, and the potential delivery of new bacteria by meteors and comets. Asgardia could help by providing a capable space-based resource, or even just another place for humans to safely live. As described by Ashurbeyli "The ultimate aim is to create a legal platform to ensure protection of planet Earth, and to provide access to space technologies for those who do not have that access at the moment."

At present Asgardia don't have direct programmes to build space hardware independently. They do intend to pursue a national programme of space research, so they may well become involved in space construction once they have a real presence in orbit. Although they will also have a business arm, so their first real territory, rather than digital, will probably be buildings acquired around the world to host the Asgardian administration. In the event that they secure United Nations recognition, these places on Earth would then gain the same status as conventional embassies and consulates of existing nations.

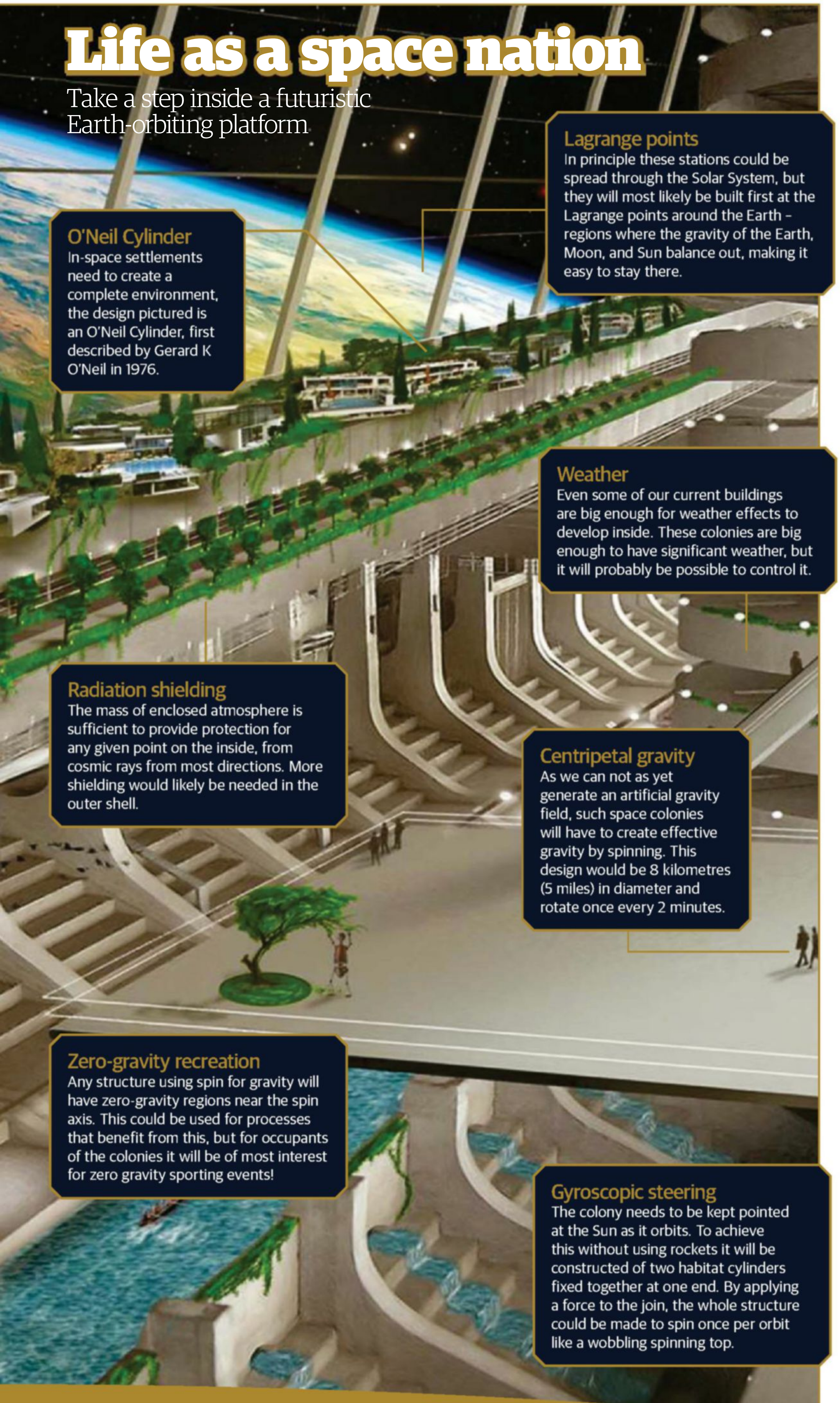
Space settlement has long held out the dream of creating personal utopia, adjusted to your particular politics. Interwar Russia dreamed of communist revolution on Mars, while some American libertarians hope to recapture the supposed freedom of the American frontier, free from 'big government'. But Asgardia's approach is much more pragmatic: the constitution includes the right to private property, inheritance and free enterprise, but a commitment to an equitable distribution of wealth, collective cooperation for the community, ethical responsibility and personal freedom of expression are equal tenets, too.

This is practical as well as truly ideological. When it comes to real space settlements, isolated in a lethal environment a community would have to work collectively for survival. Solitary libertarians would find such government far too 'big', but settlers could be particularly stuck if management turned totalitarian, as the only border would be to the vacuum of space. By starting with the community developed constitution, and distributing territory and responsibility across the digital nation, and later the Solar System, Asgardia hope to create a firm foundation, and protect their future from extremes. But with the whole Solar System open to explore, if Asgardia demonstrates that it is possible to establish a new nation, how many more might follow?

Ashurbeyli's professional track record in science, in business and in international affairs is impressive; he is certainly a much more credible founder than many prospective nation builders, even many that would have actual Earthly territory to point to. Asgardia is a tremendously ambitious conception, and their predicted timetable very short, but they have attracted a rapidly growing population of many talents very quickly, and diverse affordable, independent access to space is finally arriving. Ashurbeyli's term of five years up to 2022 will probably show whether Asgardia will survive and grow into an actual nation to the benefit of humanity. We may see Asgardia's name plate at the United Nations much sooner than we expect, and perhaps by 2030 it will be the space holiday destination of choice!

Life as a space nation

Take a step inside a futuristic Earth-orbiting platform



O'Neil Cylinder
In-space settlements need to create a complete environment, the design pictured is an O'Neil Cylinder, first described by Gerard K O'Neil in 1976.

Lagrange points
In principle these stations could be spread through the Solar System, but they will most likely be built first at the Lagrange points around the Earth – regions where the gravity of the Earth, Moon, and Sun balance out, making it easy to stay there.

Weather
Even some of our current buildings are big enough for weather effects to develop inside. These colonies are big enough to have significant weather, but it will probably be possible to control it.

Radiation shielding
The mass of enclosed atmosphere is sufficient to provide protection for any given point on the inside, from cosmic rays from most directions. More shielding would likely be needed in the outer shell.

Centripetal gravity
As we can not as yet generate an artificial gravity field, such space colonies will have to create effective gravity by spinning. This design would be 8 kilometres (5 miles) in diameter and rotate once every 2 minutes.

Zero-gravity recreation
Any structure using spin for gravity will have zero-gravity regions near the spin axis. This could be used for processes that benefit from this, but for occupants of the colonies it will be of most interest for zero gravity sporting events!

Gyroscopic steering
The colony needs to be kept pointed at the Sun as it orbits. To achieve this without using rockets it will be constructed of two habitat cylinders fixed together at one end. By applying a force to the join, the whole structure could be made to spin once per orbit like a wobbling spinning top.

STARGAZER

GUIDES AND ADVICE TO GET STARTED IN AMATEUR ASTRONOMY

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Saturn's still hanging around, while Mars and Venus are visible in the early morning

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Darker skies mean that some trickier deep-sky targets come out to shine

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What's in the sky?

13 OCT
The Moon and the Beehive Cluster (M44) make a close approach in Cancer

13 OCT
Conjunction between the Moon and dwarf planet Ceres in Cancer

14 OCT
Messier 33 is well placed for observation, reaching a magnitude of 5.7 in Triangulum

18 OCT
Conunction between the Moon, Makemake and Venus in Virgo and Coma Berenices

19 OCT
Uranus reaches opposition, glowing at magnitude 5.7 in the constellation Pisces

20 OCT
Conjunction between the Moon, dwarf planet Haumea and Mercury in Virgo and Boötes

26 OCT
Open star cluster NGC 869 in Perseus is glowing at magnitude 4.0 in Perseus

26 OCT
Conjunction between the Moon and dwarf planet Pluto in Sagittarius

27 OCT
Open star cluster NGC 884 is well placed for observation, glowing at magnitude 4 in Perseus

©ESO/Digitized Sky Survey 2

30 OCT
The Fornax Dwarf galaxy is well placed for observation, at magnitude of 9.0 in Fornax

1 NOV
Conjunction between Jupiter and dwarf planet Haumea in Virgo and Boötes

Jargon buster

Conjunction

A conjunction is an alignment of objects at the same celestial longitude. The conjunction of the Moon and the planets is determined with reference to the Sun. A planet is in conjunction with the Sun when it and Earth are aligned on opposite sides of the Sun.

Right Ascension (RA)

Right Ascension is to the sky what longitude is to the surface of the Earth, corresponding to east and west directions. It is measured in hours, minutes and seconds since, as the Earth rotates on its axis, we see different parts of the sky throughout the night.

Declination (Dec)

This tells you how high an object will rise in the sky. Like Earth's latitude, Dec measures north and south. It's measured in degrees, arcminutes and arcseconds. There are 60 arcseconds in an arcminute and there are 60 arcminutes in a degree.

Magnitude

An object's magnitude tells you how bright it appears from Earth. In astronomy, magnitudes are represented on a numbered scale. The lower the number, the brighter the object. So, a magnitude of -1 is brighter than an object with a magnitude of +2.

Opposition

When a celestial body is in line with the Earth and Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter.

Greatest elongation

When the inner planets, Mercury and Venus, are at their maximum distance from the Sun. During greatest elongation, the inner planets can be observed as evening stars at greatest eastern elongations and as morning stars during western elongations.

Red light friendly

In order to preserve your night vision, you should read our observing guide under red light

©Alexander Meleg

15 OCT
Comet C/2017 O1 (ASASSN) will make its closest approach to the Sun in Perseus

16 OCT
Comet C/2017 O1 (ASASSN) is predicted to reach its brightest at magnitude 8.1 in Perseus

21 OCT
The Orionids reach their peak of 25 meteors per hour

23 OCT
Asteroid 2 Pallas reaches opposition, glowing at a magnitude of 8.2 in Eridanus

24 OCT
Conjunction between the Moon and dwarf planet Pluto in Sagittarius

27 OCT
Conjunction between Venus and dwarf planet Makemake in Virgo and Coma Berenices

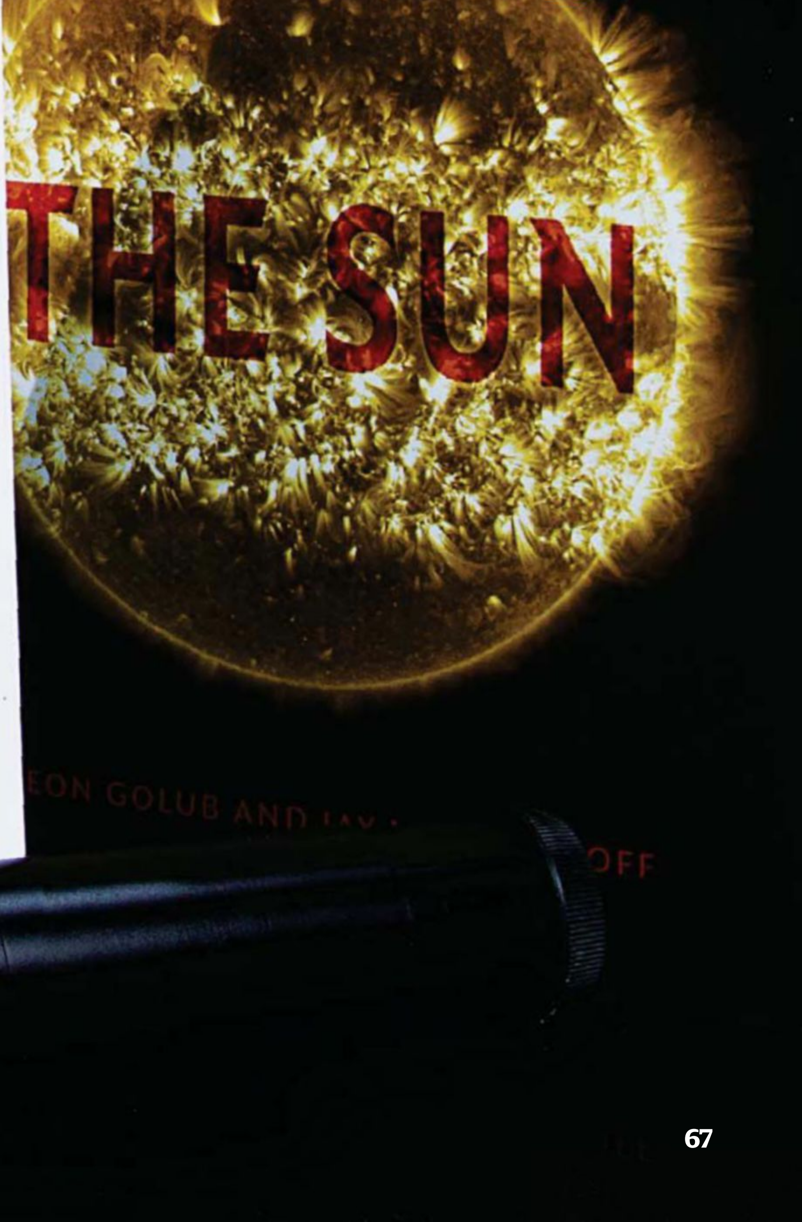
30 OCT
Asteroid Iris reaches opposition, glowing at magnitude 6.8 in Aries

30 OCT
The Moon and Neptune make a close approach, passing within 0°50′ of each other in Aquarius

3 NOV
Conjunction between the Moon and dwarf planet Eris in Pisces and Cetus

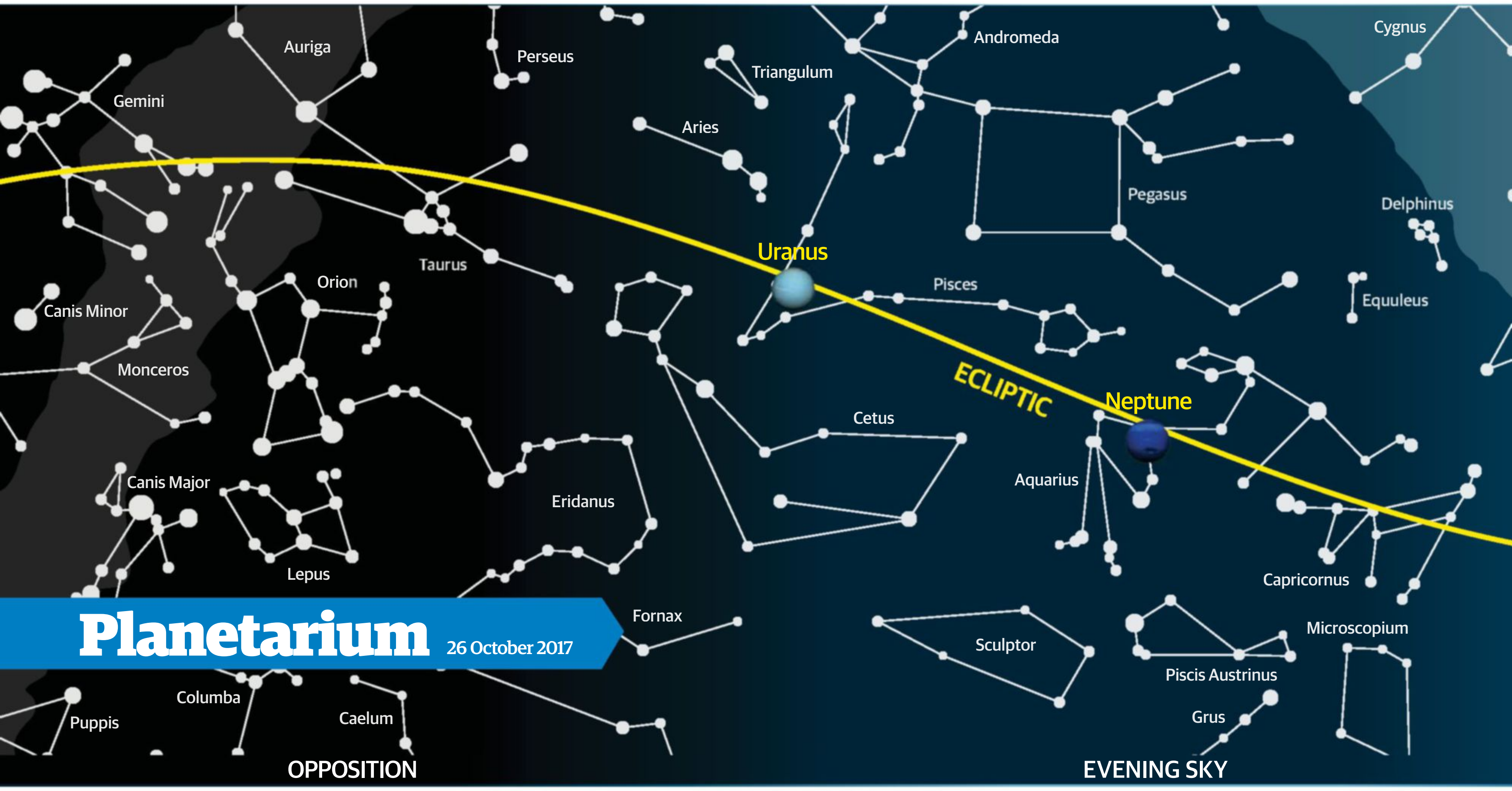
4 NOV
The Taurids reach their peak of 10 meteors per hour

- Naked eye
- Binoculars
- Small telescope
- Medium telescope



Planetarium

26 October 2017



Moon phases

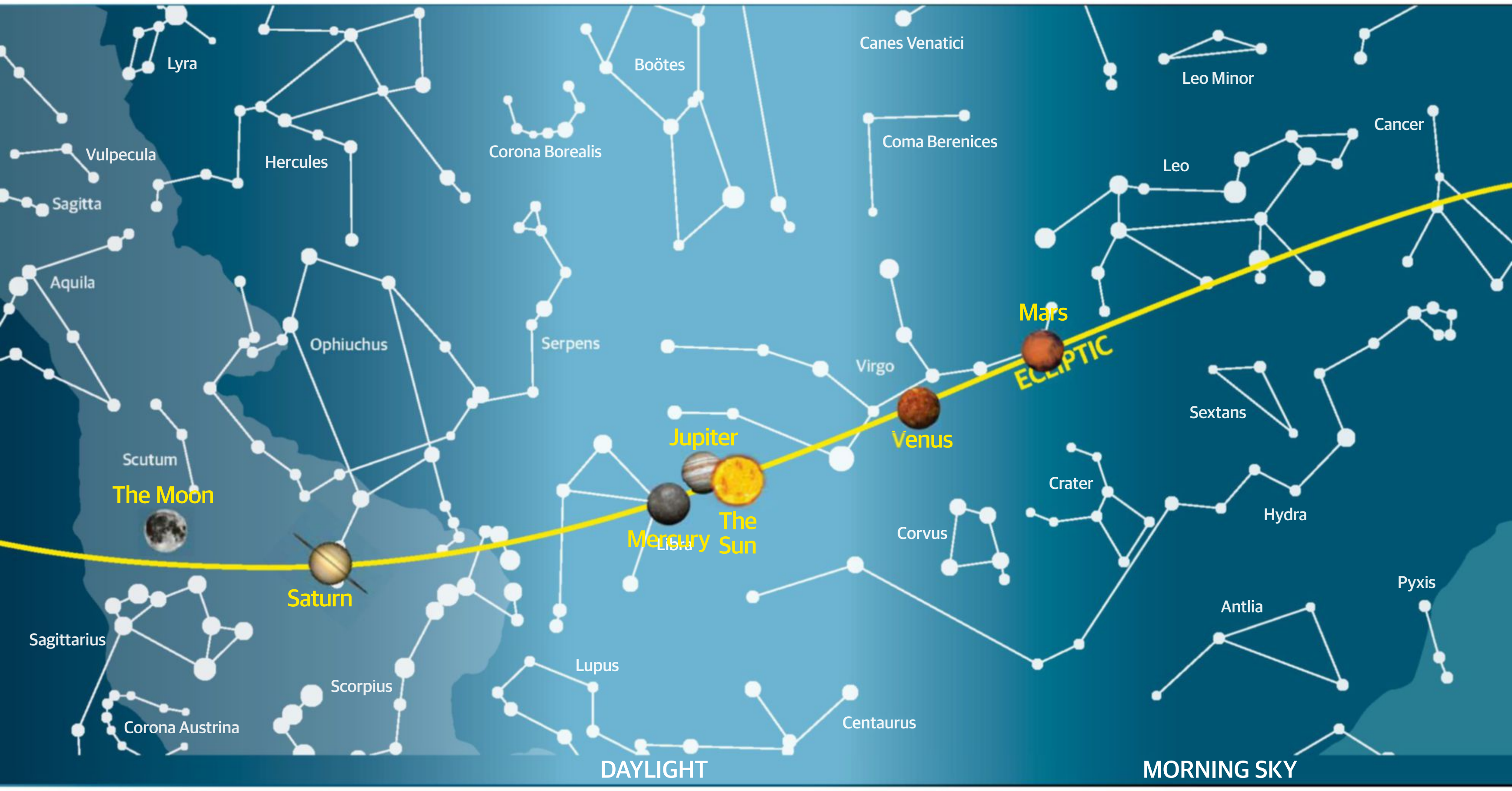
* The Moon does not pass meridian on 4 November

			12 OCT LQ 53.5% ◓23:41 ◒14:43	**13 OCT** 41.6% ◓- ◒15:29	**14 OCT** 30.4% ◓00:50 ◒16:08	**15 OCT** 20.5% ◓02:01 ◒16:39
16 OCT 12.3% ◓03:14 ◒17:07	**17 OCT** 6.1% ◓04:26 ◒17:32	**18 OCT** 2.0% ◓05:37 ◒17:55	**19 OCT** NM 0.3% ◓06:46 ◒18:19	**20 OCT** 0.7% ◓07:54 ◒18:43	**21 OCT** 3.2% ◓09:01 ◒19:09	**22 OCT** 7.6% ◓10:05 ◒19:39
23 OCT 13.6% ◓11:07 ◒20:13	**24 OCT** 21.0% ◓12:04 ◒20:52	**25 OCT** 29.4% ◓12:56 ◒21:37	**26 OCT** 38.6% ◓13:42 ◒22:29	**27 OCT** FQ 65.9% ◓14:23 ◒23:26	**28 OCT** 58.3% ◓14:58 ◒-	**29 OCT** 68.2% ◒00:28 ◓14:29
30 OCT 77.5% ◒00:34 ◓14:56	**31 OCT** 85.9% ◒01:43 ◓15:22	**1 NOV** 92.8% ◒02:55 ◓15:47	**2 NOV** 97.6% ◒04:11 ◓16:12	**3 NOV** 99.7% ◒05:28 ◓16:40	**4 NOV** FM N/A* ◒06:48 ◓17:12	**5 NOV** 98.9% ◒08:09 ◓17:49
6 NOV 95.0% ◒09:26 ◓18:34	**7 NOV** 88.2% ◒10:38 ◓19:28	**8 NOV** 79.2% ◒11:39 ◓20:30	**9 NOV** 68.5% ◒12:30 ◓21:39			

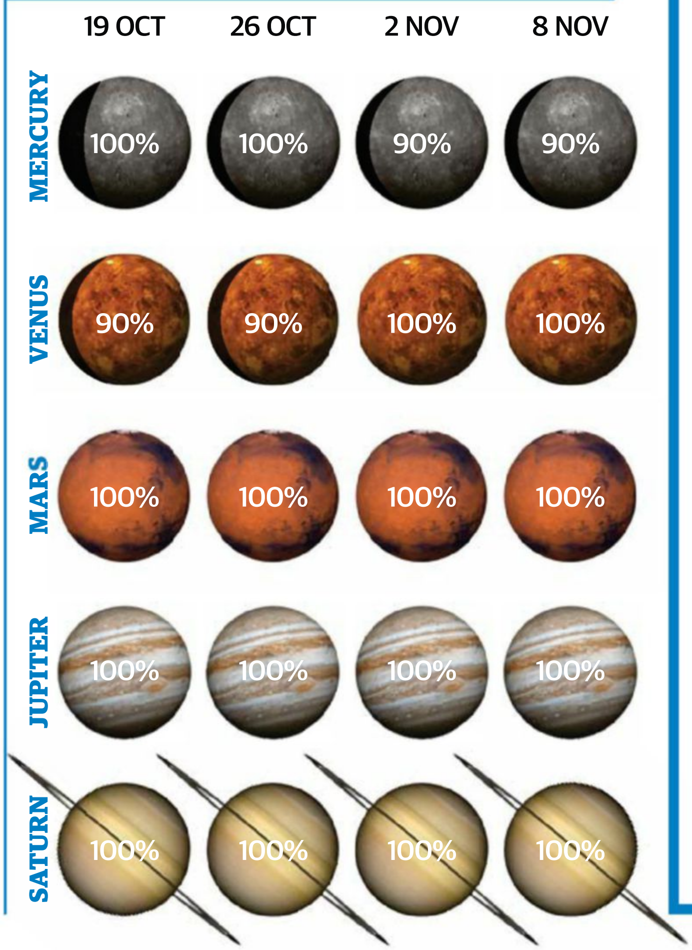
% Illumination
◓ Moonrise time
◒ Moonset time

FM Full Moon
NM New Moon
FQ First quarter
LQ Last quarter

All figures are given for 00h at midnight (local times for London, UK)



Illumination percentage



	19 OCT	26 OCT	2 NOV	8 NOV
MERCURY	100%	100%	90%	90%
VENUS	90%	90%	100%	100%
MARS	100%	100%	100%	100%
JUPITER	100%	100%	100%	100%
SATURN	100%	100%	100%	100%

Planet positions

All rise and set times are given in BST/GMT

	Date	RA	Dec	Constellation	Mag	Rise	Set
MERCURY	12 Oct	13h 18m 24s	-07° 25' 22"	Virgo	-1.4	07:27	18:19
	19 Oct	14h 01m 09s	-12° 18' 58"	Virgo	-0.9	08:08	18:09
	26 Oct	14h 43m 21s	-16° 38' 25"	Libra	-0.6	08:47	17:59
	2 Nov	15h 25m 35s	-20° 16' 23"	Libra	-0.4	08:24	16:51
	8 Nov	16h 01m 50s	-22° 44' 41"	Scorpius	-0.3	08:53	16:48
VENUS	12 Oct	11h 50m 27s	+02° 38' 40	Virgo	-3.9	05:09	17:43
	19 Oct	12h 22m 26s	-00° 45' 14"	Virgo	-3.9	05:30	17:30
	26 Oct	12h 54m 32s	-04° 10' 13"	Virgo	-3.9	05:52	17:17
	2 Nov	13h 26m 57s	-07° 31' 58"	Virgo	-3.9	05:14	16:05
	8 Nov	13h 55m 10s	-10° 19' 00"	Virgo	-3.9	05:33	15:55
MARS	12 Oct	11h 35m 58s	+03° 51' 59"	Leo	1.8	04:48	17:34
	19 Oct	11h 52m 13s	+02° 06' 14"	Virgo	1.8	04:46	17:14
	26 Oct	12h 08m 26s	+00° 20' 10"	Virgo	1.8	04:43	16:54
	2 Nov	12h 24m 38s	-01° 25' 40"	Virgo	1.8	03:41	15:34
	8 Nov	12h 38m 33s	-02° 55' 50"	Virgo	1.8	03:39	15:16
JUPITER	12 Oct	13h 53m 23s	-10° 32' 06"	Virgo	-1.7	08:19	18:38
	19 Oct	13h 59m 10s	-11° 04' 05"	Virgo	-1.7	08:00	18:13
	26 Oct	14h 05m 00s	-11° 35' 43"	Virgo	-1.7	07:41	17:49
	2 Nov	14h 10m 53s	-12° 06' 48"	Virgo	-1.7	06:22	16:24
	8 Nov	14h 15m 55s	-12° 32' 53"	Virgo	-1.7	06:06	16:03
SATURN	12 Oct	17h 28m 29s	-22° 11' 58"	Ophiuchus	0.5	13:02	21:04
	19 Oct	17h 30m 46s	-22° 14' 42"	Ophiuchus	0.5	12:37	20:38
	26 Oct	17h 33m 18s	-22° 17' 25"	Ophiuchus	0.5	12:12	20:13
	2 Nov	17h 36m 03s	-22° 20' 03"	Ophiuchus	0.5	10:48	18:48
	8 Nov	17h 38m 34s	-22° 22' 11"	Ophiuchus	0.5	10:27	18:27

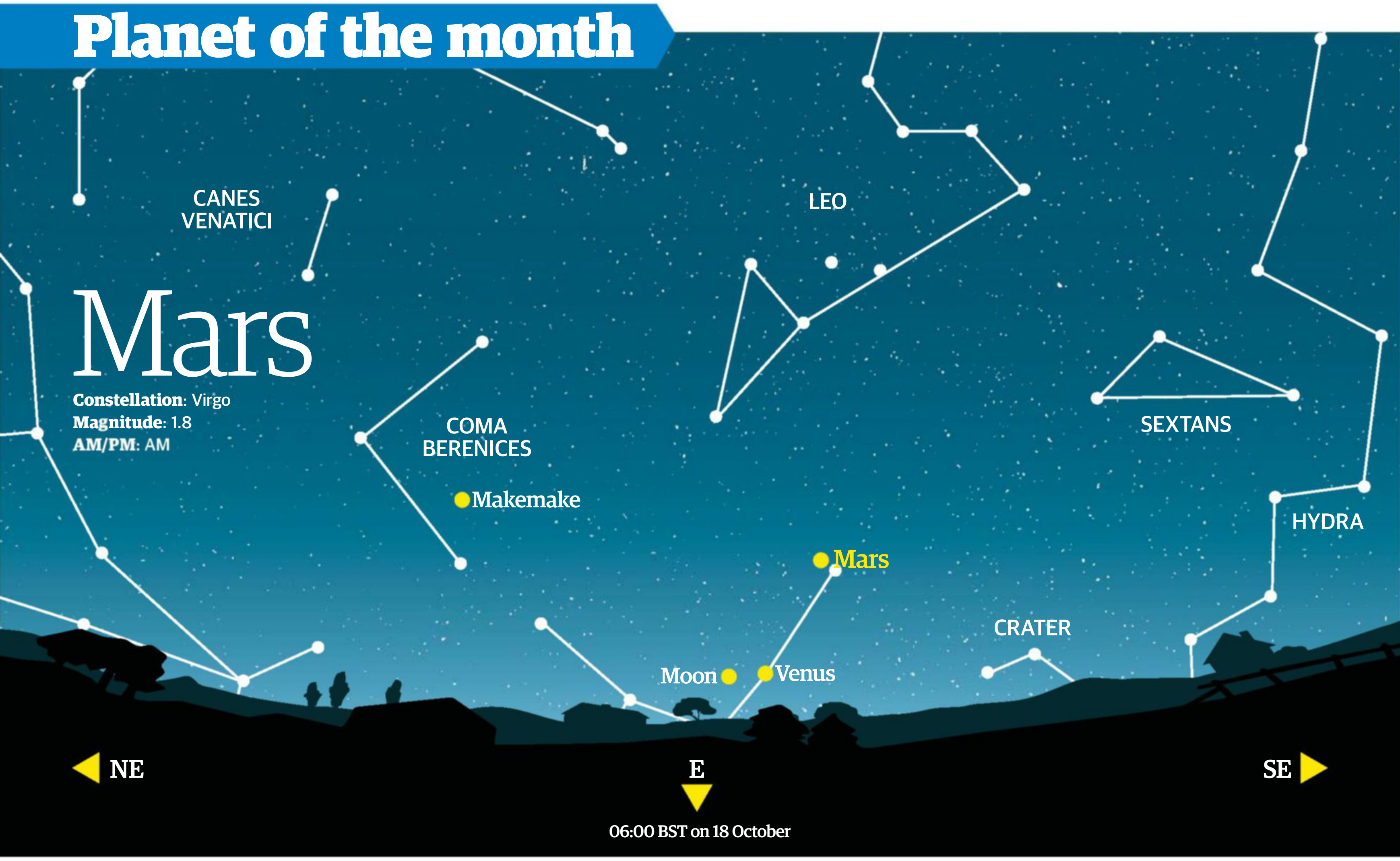
This month's planets

The Red Planet gets ready for a dazzling show in Virgo, while Uranus and Saturn remain in view

Planet of the month

Mars

Constellation: Virgo
Magnitude: 1.8
AM/PM: AM



06:00 BST on 18 October

Usually our 'Planet of the Month' is chosen because it is either particularly bright in the sky, well placed for observation or both. This month's planet was picked specifically because it is neither of those things. Why?

The Red Planet is nothing much to look at this month. It's really just killing time, taking a rest before dazzling us with its close approach next year. That makes this a great time to look at Mars because seeing it at its least impressive now, how it usually looks, will make you appreciate it all the more next year.

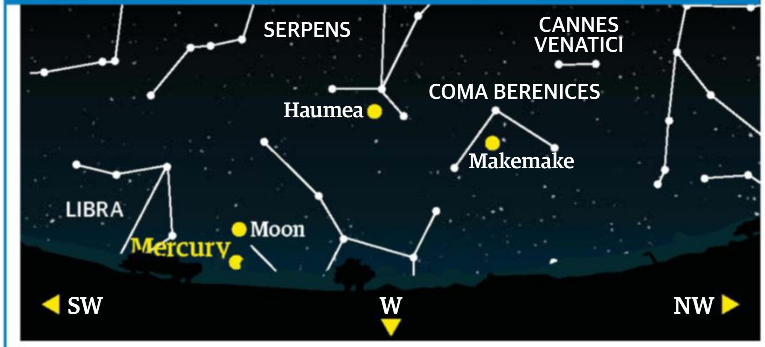
This time next year Mars will be a striking sight - a bright-orange spark that will dominate everything else around it. Even a small telescope will show details on its disc, such as its bright ice caps and the dark shark fin of Syrtis Major. However, this month Mars is an unremarkable-looking red star in the morning sky, visible low in the east for a couple of hours before sunrise. It is put to shame by brilliant Venus, which will be nearby, and all the bright stars in the sky too.

Shining at magnitude 1.8, Mars will be roughly the same brightness as Alkaid, the star on the end of the Big Dipper's handle, and only a little brighter than the Pole Star. However, the Red Planet's low altitude in that brightening morning sky will make it seem much fainter than those stars. You may well be surprised by just how much it blends into the background.

If you need some help tracking down Mars, the Moon will come to your rescue on the morning of 17 October. If you get up before dawn on that date, look east and you'll see a very thin crescent Moon shining close to Mars, to the planet's upper right. The two worlds will be just two-and-a-half degrees - or five Moon widths - apart, and will look very pretty together in binoculars.

Looking at Mars in the sky, it's impossible not to wonder when people will set foot on it. We have sent many landers and several rovers to the planet. Some failed before or soon after landing, others carried out extensive research on the planet, paving the way for astronauts to follow. A crewed Mars mission has been a dream of space agencies and enthusiasts alike since the heady days of Apollo, but we seem no nearer to watching astronauts plant a flag on the surface of Mars now than when Armstrong took his famous small step. No space agency has a firm timeline for a crewed Mars mission. If NASA's mighty new SLS rocket performs as it should we might see a crewed Orion capsule fly to and around Mars without landing in the late 2020s, but don't bet on it. For now, just look at Mars shining quietly in the morning sky, and imagine the glorious day when people stand on it for the first time.

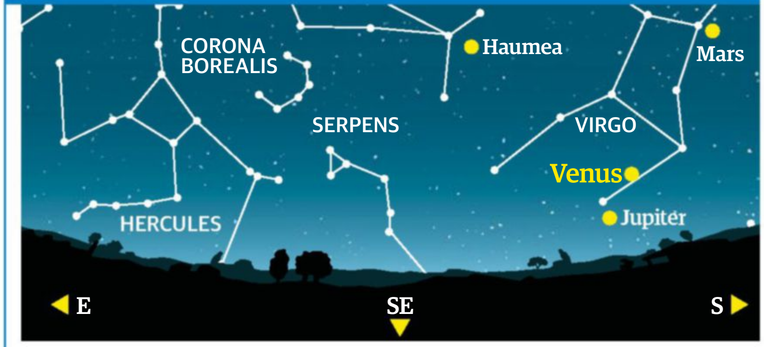
Mercury 18:00 BST on 20 October



Constellation: Virgo into Libra
Magnitude: -0.5
AM/PM: PM

If you want a good look at Mercury this month, you can't, it's as simple as that. The tiny world is just too close to the Sun. In theory there's a chance you might just catch a fleeting glimpse of it in late October, when it will be very low in the west for 15 short minutes after sunset, but to see its copper-hued pinprick you'll need to sweep that area of the sky with binoculars, and only after the Sun has vanished.

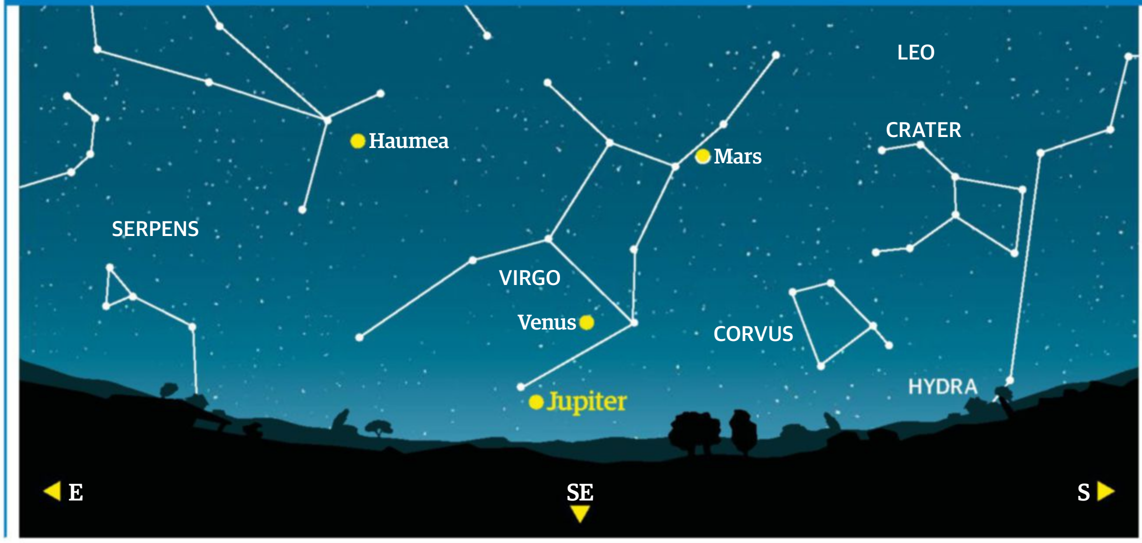
Venus 07:00 GMT on 7 November



Constellation: Virgo
Magnitude: -3.9
AM/PM: AM

To the naked eye it is a strikingly bright, white spark. Through a telescope Venus will show an almost full disc that will slowly shrink in size as the days and weeks pass. The waning crescent Moon will approach and then pass Venus (and nearby Mars) between 16 and 18 October, the best view being early on the 17 October, when a fingernail clipping-thin Moon will shine very close to both worlds.

Jupiter 06:30 GMT on 4 November

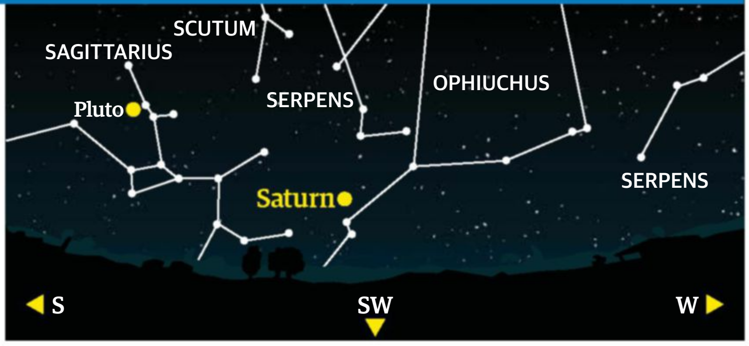


Constellation: Virgo
Magnitude: -1.7
AM/PM: AM

As we move into the twilight of the year, Jupiter – usually happy to dominate the sky as it has been for most of summer – is doing its very best to stay out of view.

In fact, you'll really struggle to see the giant planet at all this month, because it will be so close to the Sun, actually passing behind it as seen from here on Earth. You might just catch a glimpse of it in early November, when it will have emerged from behind our nearest star, but only if you get up really early and have a completely flat eastern horizon to sweep above with binoculars before sunrise, but even then it's unlikely you'll pull it out of the bright sky.

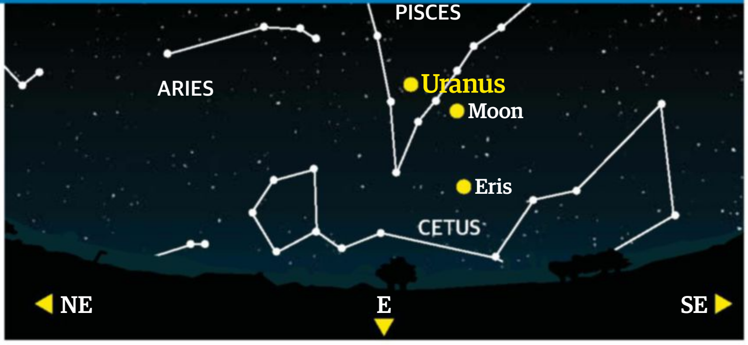
Saturn 17:30 GMT on 4 November



Constellation: Ophiuchus
Magnitude: 0.5
AM/PM: PM

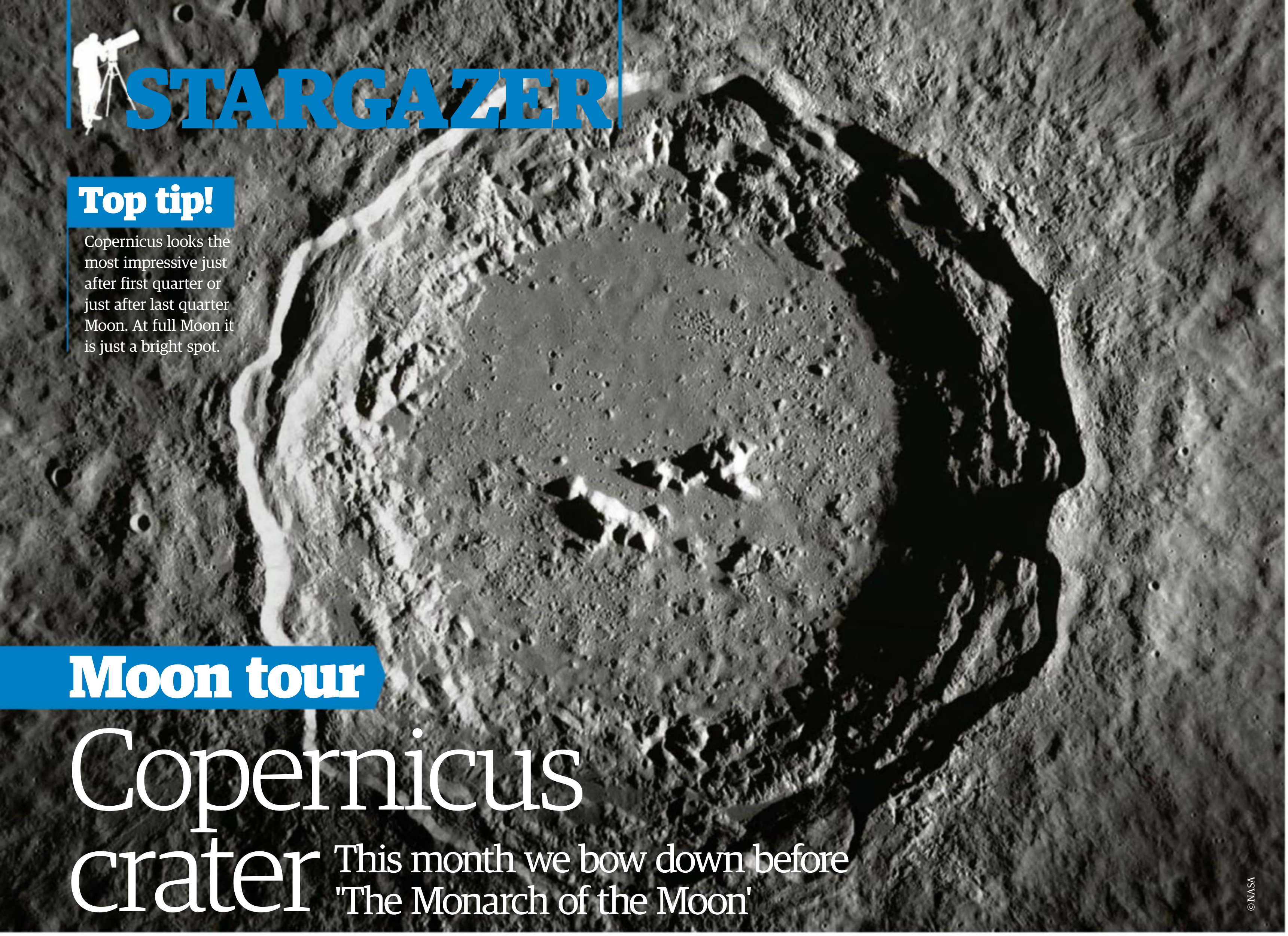
It seems like Saturn has been hanging around the southern part of the sky for an eternity. It's still there during this month, low in the south after sunset, setting a little earlier each evening. It still looks like a gold-coloured star to the naked eye, but it's not as easy to pick out now as it was back in the summer. It is approached and then passed by a beautiful crescent Moon between 23 and 25 October.

Uranus 18:00 GMT on 2 November



Constellation: Pisces
Magnitude: 5.7
AM/PM: PM

With a magnitude of 5.7, Uranus is technically a naked eye object under unpolluted skies. A pair of binoculars helps isolate the planet from the background stars, and a telescope will reveal it as a tiny disc with a subtle, yet distinctive, green colour. This month Uranus is visible all through the night. The almost-full Moon will be just four and a half degrees away from Uranus on the evening of 3 November.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Top tip!

Copernicus looks the most impressive just after first quarter or just after last quarter Moon. At full Moon it is just a bright spot.

Moon tour

Copernicus crater

This month we bow down before 'The Monarch of the Moon'

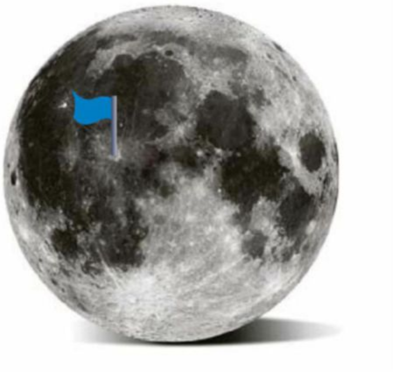
Ask any group of Moon observers - absolute beginner or more experienced - to name their favourite lunar crater and chances are most will nominate the same feature: Copernicus.

Copernicus has a nickname - 'The Monarch of the Moon' - and if you've only ever seen photographs of the crater but never seen it with your own eyes, you would be forgiven for thinking that sounds a bit pompous. But, just as every amateur astronomer remembers their first view of Saturn and its rings through a telescope or their first display of the northern lights, they never forget the first time they saw Copernicus through a telescope. In fact, the crater is one of the first things a beginner will see through a pair of humble binoculars because it stands out so starkly on the Moon, even when viewed under 10x magnification through a shaking pair of binoculars on a chilly October night.

Copernicus was formed in fire and fury. Some time between 800 million and 1 billion years ago, the Moon collided with a large asteroid. The explosion caused by the impact blasted an enormous hole out of the area of the Moon we now know as Oceanus Procellarum, or 'The Ocean Of Storms'. The gaping pit left behind was almost four kilometres deep and more than 93 kilometres (58 miles) wide, which means its opposite walls are as far apart as London and Clacton-on-Sea. The impact didn't just excavate a hole; it sent an enormous debris cloud of dust and rocks billowing up into the sky and across the lunar landscape. Some of that material fell back down to the Moon, spraying across it and leaving bright rays of ejecta splashed on the landscape. These 'debris rays' are so bright and so long - the longest stretches for over 800 kilometres (497 miles), the distance between London and John O'Groats - that they can even be seen with the naked eye when the Moon is full, looking like white chalk lines drawn on the Moon's rugged grey-blue face.

The crater itself lies just south of Montes Carpatus (Carpathian Mountains) a short range of mountains on the southern shore of Mare Imbrium. Copernicus is roughly circular in shape, and its walls are terraced on all sides with a wide shelf dropped down on the western side, and landslides in several places. The crater's floor is quite flat, with a plain of ancient lava pocked here and there, and much smaller, much younger craterlets. In the centre of the crater a trio of mountains protrude from the lava plain, the tallest with a peak of one kilometre above the crater's floor.

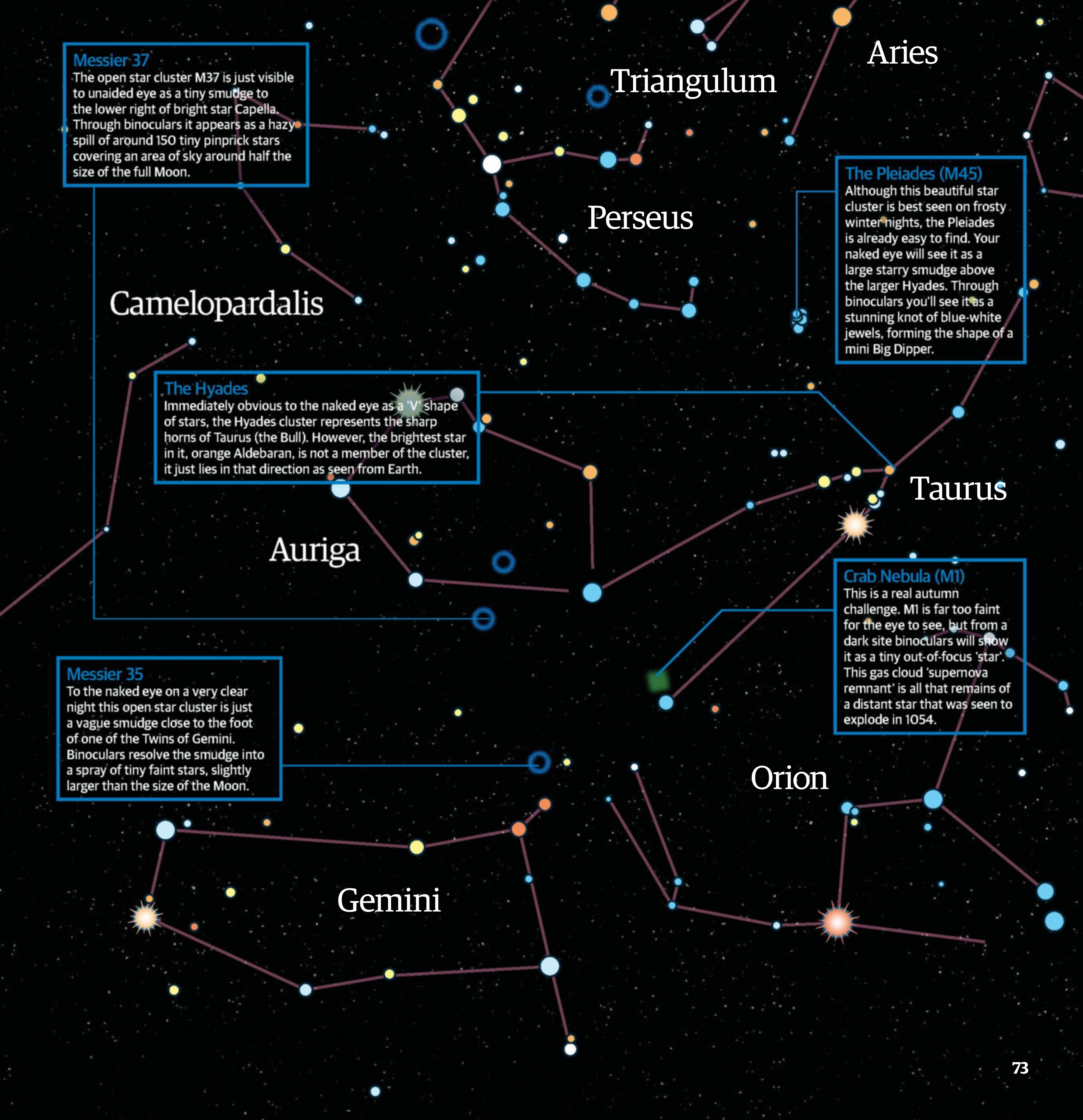
Another of Copernicus' claims to fame is that it is relatively near one of the Apollo landing sites. In November 1969 Pete Conrad and Alan Bean guided the Apollo 12 lunar module 'Intrepid' down to a landing site a little over 240 kilometres (150 miles) south of the huge crater. Their incredible precision landing placed them within walking distance of the unmanned Surveyor 3 probe, which had landed two and a half years earlier. The astronauts removed pieces of the probe and brought them to Earth for indepth study.



Copernicus is fully illuminated at the start of our observing period (12 October), when the Moon will be a waning crescent glowing in the east before dawn. With the Sun's light slanting in at a low angle from the west, the crater will stand out from its surroundings and will be an impressive sight in a telescope. Magnified 100x or more it looks like an empty eye socket staring back at you from across space. However, it will only be visible until the morning of the 15 October, when the terminator will sweep over, plunging the lunar surface into darkness. The crater will then be hidden from view until 29 October when it emerges into the sunlight again, when the Moon is just past first quarter. As the nights pass the crater's appearance will change, its sharp outline and interior details blurring away as the Sun climbs higher in the lunar sky. When the Moon reaches full on 4 November, Copernicus will be reduced to a flattened, light disc streaked by impressively bright rays.

This month's naked eye targets

The cold, crisp nights of autumn offer sky-watchers many tempting targets...



Messier 37
The open star cluster M37 is just visible to unaided eye as a tiny smudge to the lower right of bright star Capella. Through binoculars it appears as a hazy spill of around 150 tiny pinprick stars covering an area of sky around half the size of the full Moon.

The Pleiades (M45)
Although this beautiful star cluster is best seen on frosty winter nights, the Pleiades is already easy to find. Your naked eye will see it as a large starry smudge above the larger Hyades. Through binoculars you'll see it as a stunning knot of blue-white jewels, forming the shape of a mini Big Dipper.

The Hyades
Immediately obvious to the naked eye as a 'V' shape of stars, the Hyades cluster represents the sharp horns of Taurus (the Bull). However, the brightest star in it, orange Aldebaran, is not a member of the cluster, it just lies in that direction as seen from Earth.

Crab Nebula (M1)
This is a real autumn challenge. M1 is far too faint for the eye to see, but from a dark site binoculars will show it as a tiny out-of-focus 'star'. This gas cloud 'supernova remnant' is all that remains of a distant star that was seen to explode in 1054.

Messier 35
To the naked eye on a very clear night this open star cluster is just a vague smudge close to the foot of one of the Twins of Gemini. Binoculars resolve the smudge into a spray of tiny faint stars, slightly larger than the size of the Moon.

STARGAZER

GUIDES AND ADVICE TO GET STARTED IN AMATEUR ASTRONOMY

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Your guide to the perfect telescope

You've decided to buy a new instrument – but which one should you get?

Written by Stuart Atkinson

Even though you can see a lot of beautiful and amazing things in the night sky with just your naked eye or a pair of binoculars on a sparkling-clear night, for most people astronomy equals telescopes. Do a search for 'stargazing' and you will be presented with countless images of wide-eyed, happy people looking into or standing next to telescopes, usually beneath a totally cloud-free sky dusted with stars. Magazines are full of adverts for telescopes, and astronomy websites and blogs are packed with accounts of how beautiful star clusters, galaxies and nebulae look through them. Naturally every stargazer eventually reaches the point where they decide they want a telescope of their own so they can gaze upon the wonders of the universe. But there are so many telescopes to choose from! Which one would be the perfect telescope for you? Simple – the one you will actually use.

And how do you know in advance which telescope you will use? Just as you might do before buying a car, a house or even a new laptop, you have to ask yourself some questions – and answer them honestly. If you do that you'll learn that some telescopes will be too big and heavy for you to use, and some will not be powerful enough to let you see what you want to see. You'll realise that some telescopes will just be too complicated to set up, and some will be too basic to meet your needs. You'll also realise that some telescopes are just way beyond your budget, too.

When you've figured out what you really want to see through a telescope, where you will be using it, how much you can afford to pay for one and so forth, then you can make a decision and head to the cash machine. We're going to help you get to that point – because if you buy the wrong telescope for you it will probably put you off astronomy for good.

What do I need to know before choosing a telescope?

- ☐ What do I want to see through my telescope - the Moon and planets? Faint objects such as galaxies, clusters and nebulae?
- ☐ Where do I want to use my telescope - away from home at a dark-sky site, or just from my garden?
- ☐ Am I really ready for a telescope - do I know the night sky well enough to find what I'm looking for?
- ☐ How much can I afford - what is my budget for a telescope?
- ☐ Do I want to take photographs through my telescope, or just use it visually?

The Reflector

These use a series of mirrors for observations, and are great for viewing distant galaxies and nebulae

As their name suggests, reflector telescopes use mirrors instead of lenses. They are basically a tube, open at the front, with a large mirror mounted down the bottom end. Light from the night sky enters the tube, hits the mirror, reflects off it back up and is diverted out of the tube's side by a smaller, secondary mirror, into a focusing eyepiece.

It is generally accepted that the first working reflector was built by Sir Isaac Newton back in 1668, although others had designed similar instruments before him. Almost 350 years later, reflectors are probably the most popular type of telescope. Not just because they are a good general-purpose telescope, which can be used for viewing both deep-sky and Solar-System objects, but because an entry-level reflector, with a mirror six to eight-inches across, can be bought for a very reasonable sum. In fact, in terms of cost per inch of aperture, a reflector is definitely better value for money than a refractor.

When seen standing next to fragile-looking, thin-tubed refractors their sturdy, cannon-like tubes make them look very impressive and powerful. Today, go to any dark-sky star party and most telescopes in use there will be reflectors. This is because reflectors are very well suited for observing deep-sky objects. Because the objects they observe – the so-called 'faint fuzzies' such as distant galaxies and nebulae – are very far away and very faint, reflectors are perfect for observing them. They are essentially 'light buckets' which collect a lot of starlight with their wide mirrors. Under a truly dark sky even an entry-level reflector will provide wonderful views of the gracefully curving arms of spiral galaxies and the misty blossoms of nebulae. They will still give pleasing views of Solar-System objects, but their open tubes allow air to circulate inside, which reduces the sharpness of their images. When aimed at planets or the Moon they will definitely be out-performed by a refractor – with its closed tube - of similar aperture.

The cheapest and most simple reflectors to use are 'Dobsonians'. These are essentially just large telescope tubes mounted in a box-like cradle that can be swivelled around to point the telescope in any direction required. The tube itself is then tipped up or down until the target is in view in the eyepiece. The eyepiece of a reflector is found on the side of the telescope tube, not on the far end, as is the case with a refractor. This is because a small secondary mirror mounted close to the open end of the tube reflects the light to the side, and into a focuser with an eyepiece. These Dobsonians are now hugely popular and mass-produced, and it is possible to purchase a brand new Dobsonian reflector with an aperture of eight to ten-inches for a couple of hundred pounds.

One complication with reflectors is that they turn the object in the eyepiece upside down – and sometimes back to front, too – compared to the view the naked eye sees. This isn't important looking at stars or deep-sky objects, but it can be rather confusing for a beginner when they look into the eyepiece and see the Moon's features, or features on a planet, mixed up compared to what's on their charts.

Another thing to bear in mind with reflectors is that their mirror systems are sensitive to being handled and moved. Consequently, most reflector owners have to re-align – or 'collimate' – their mirrors before every use, because they have gone out of alignment. This can be tricky at first, but will soon become just another part of the set-up routine.

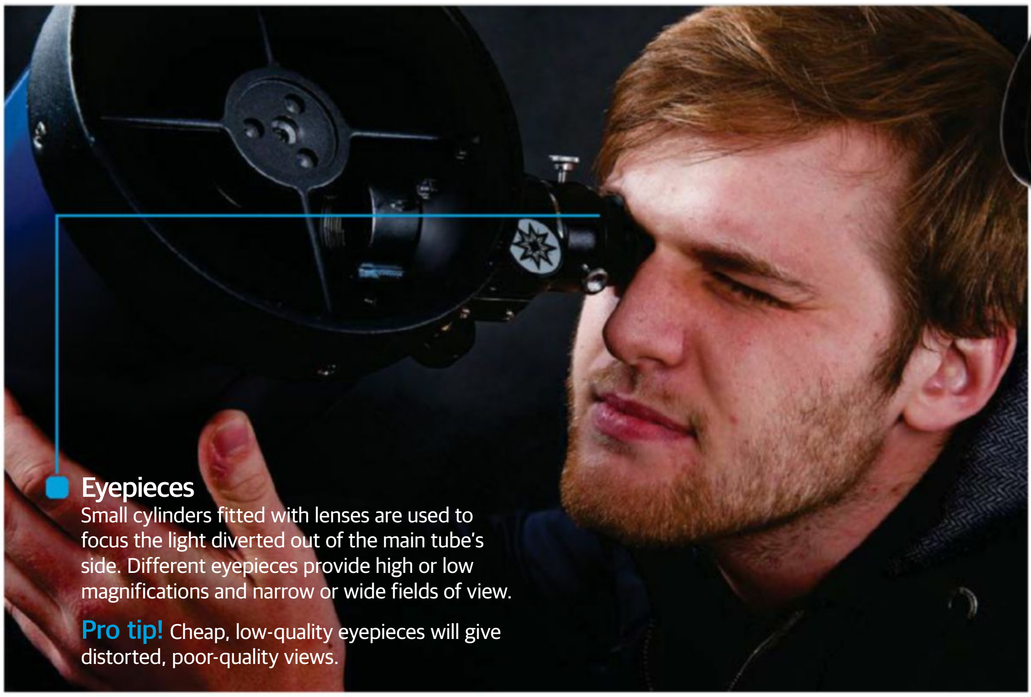
Just like refractors, modern reflectors come on a wide variety of mounts, and again, like refractors, if their tripod isn't sturdy and solid the images they produce will wobble in the eyepiece like jelly, rendering them useless.

Refractors on Dobsonian's are essentially 'point and look' telescopes, like their alt-az refractor cousins. You can also buy reflectors on the previously described, more complicated 'equatorial' mounts, and on computerised GoTo mounts too.

> "Reflectors are very well suited for observing deep-sky objects"

Is a reflector right for me?

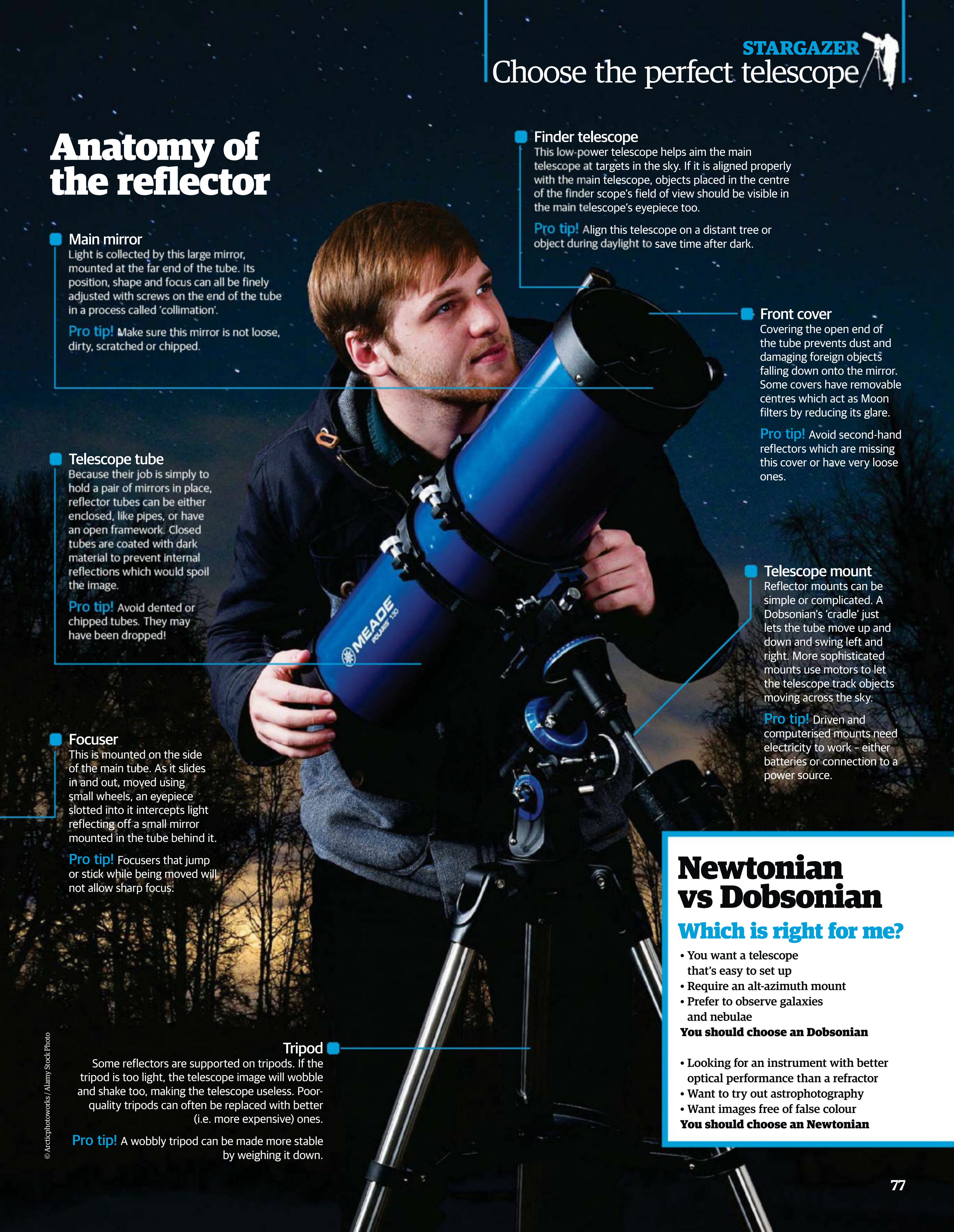
- ☐ Large-aperture, good optical quality reflectors are now available at very reasonable prices
- ☐ Popular telescope choice for observers wanting to enjoy viewing deep-sky objects such as galaxies and nebulae
- ☐ Cradle-mounted 'Dobsonian' reflectors are very easy to assemble and use



Eyepieces
Small cylinders fitted with lenses are used to focus the light diverted out of the main tube's side. Different eyepieces provide high or low magnifications and narrow or wide fields of view.

Pro tip! Cheap, low-quality eyepieces will give distorted, poor-quality views.

Anatomy of the reflector



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Main mirror

Light is collected by this large mirror, mounted at the far end of the tube. Its position, shape and focus can all be finely adjusted with screws on the end of the tube in a process called 'collimation'.

Pro tip! Make sure this mirror is not loose, dirty, scratched or chipped.

Telescope tube

Because their job is simply to hold a pair of mirrors in place, reflector tubes can be either enclosed, like pipes, or have an open framework. Closed tubes are coated with dark material to prevent internal reflections which would spoil the image.

Pro tip! Avoid dented or chipped tubes. They may have been dropped!

Focuser

This is mounted on the side of the main tube. As it slides in and out, moved using small wheels, an eyepiece slotted into it intercepts light reflecting off a small mirror mounted in the tube behind it.

Pro tip! Focusers that jump or stick while being moved will not allow sharp focus.

Finder telescope

This low-power telescope helps aim the main telescope at targets in the sky. If it is aligned properly with the main telescope, objects placed in the centre of the finder scope's field of view should be visible in the main telescope's eyepiece too.

Pro tip! Align this telescope on a distant tree or object during daylight to save time after dark.

Front cover

Covering the open end of the tube prevents dust and damaging foreign objects falling down onto the mirror. Some covers have removable centres which act as Moon filters by reducing its glare.

Pro tip! Avoid second-hand reflectors which are missing this cover or have very loose ones.

Telescope mount

Reflector mounts can be simple or complicated. A Dobsonian's 'cradle' just lets the tube move up and down and swing left and right. More sophisticated mounts use motors to let the telescope track objects moving across the sky.

Pro tip! Driven and computerised mounts need electricity to work – either batteries or connection to a power source.

Tripod

Some reflectors are supported on tripods. If the tripod is too light, the telescope image will wobble and shake too, making the telescope useless. Poor-quality tripods can often be replaced with better (i.e. more expensive) ones.

Pro tip! A wobbly tripod can be made more stable by weighing it down.

Newtonian vs Dobsonian

Which is right for me?

- You want a telescope that's easy to set up
- Require an alt-azimuth mount
- Prefer to observe galaxies and nebulae

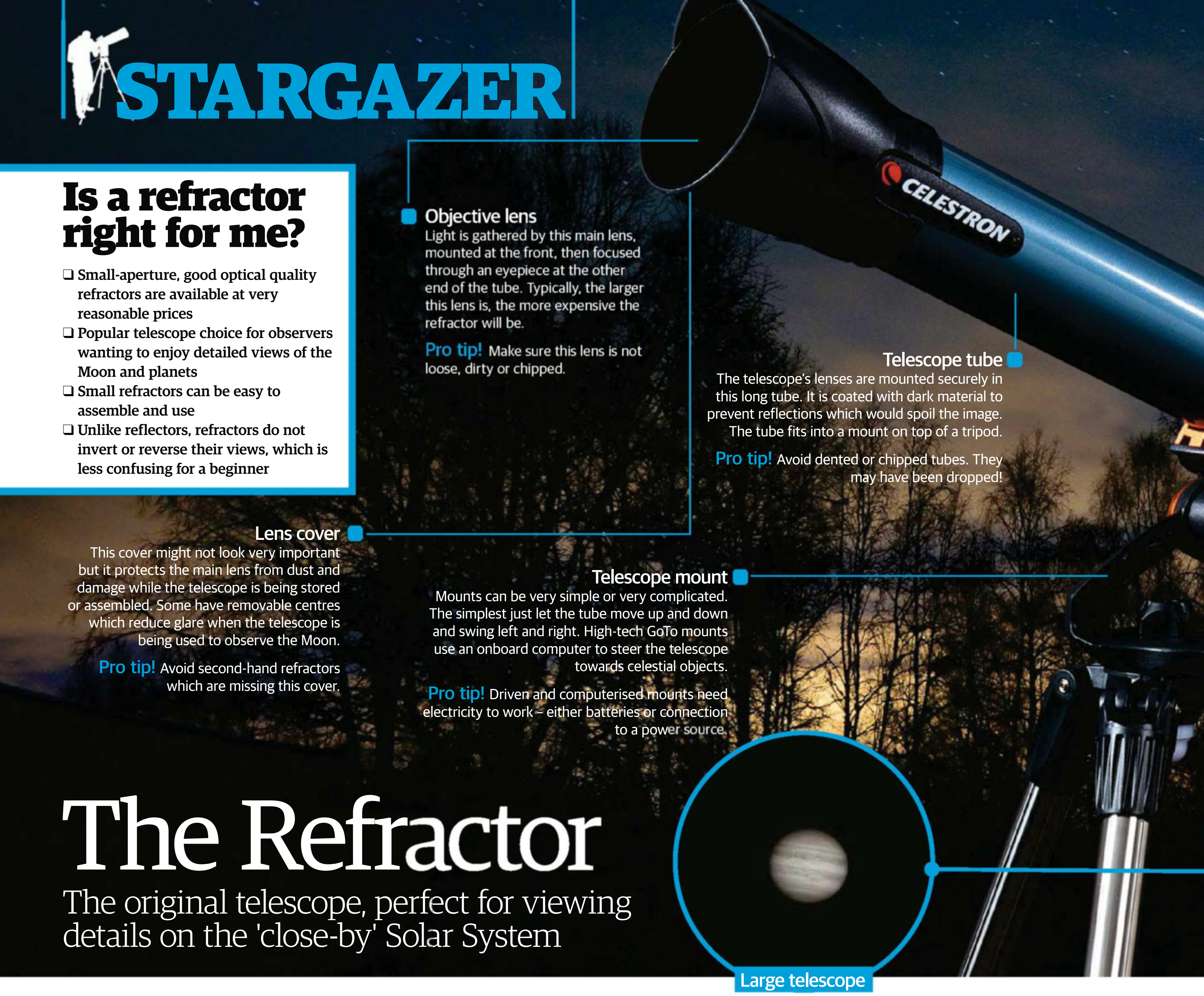
You should choose an Dobsonian

- Looking for an instrument with better optical performance than a refractor
- Want to try out astrophotography
- Want images free of false colour

You should choose an Newtonian

The Refractor

The original telescope, perfect for viewing details on the 'close-by' Solar System



Large telescope

Objective lens
Light is gathered by this main lens, mounted at the front, then focused through an eyepiece at the other end of the tube. Typically, the larger this lens is, the more expensive the refractor will be.

Pro tip! Make sure this lens is not loose, dirty or chipped.

Telescope tube
The telescope's lenses are mounted securely in this long tube. It is coated with dark material to prevent reflections which would spoil the image. The tube fits into a mount on top of a tripod.

Pro tip! Avoid dented or chipped tubes. They may have been dropped!

Lens cover
This cover might not look very important but it protects the main lens from dust and damage while the telescope is being stored or assembled. Some have removable centres which reduce glare when the telescope is being used to observe the Moon.

Pro tip! Avoid second-hand refractors which are missing this cover.

Telescope mount
Mounts can be very simple or very complicated. The simplest just let the tube move up and down and swing left and right. High-tech GoTo mounts use an onboard computer to steer the telescope towards celestial objects.

Pro tip! Driven and computerised mounts need electricity to work – either batteries or connection to a power source.

Is a refractor right for me?

- ❑ Small-aperture, good optical quality refractors are available at very reasonable prices
- ❑ Popular telescope choice for observers wanting to enjoy detailed views of the Moon and planets
- ❑ Small refractors can be easy to assemble and use
- ❑ Unlike reflectors, refractors do not invert or reverse their views, which is less confusing for a beginner

The refractor is the original telescope. In fact, it is such an iconic and classic design that when children are asked what a telescope looks like, they almost always draw or describe a refractor.

Invented around 1609 - by whom, exactly, is debated - and famously used by the great scientist Galileo to observe craters on the Moon, sunspots and to discover the four largest moons of Jupiter - a refractor is essentially a spyglass, a tube with lenses at either end which work together to make faraway objects appear closer.

If you jumped into the TARDIS and travelled back in time to the 1970s or 1980s, most telescopes bought by amateur astronomers were refractors, because good-quality reflectors were just so expensive to produce. Today the tables have been turned, and large reflectors probably outsell refractors, but high-quality refractors remain the popular telescope for astronomers wanting to enjoy detailed views of the Moon and planets. Refractors perform so well on these objects because, unlike reflectors, their tubes are closed, which means less air moving about inside them, which in turn means much less distortion of the image visible through them.

When purchasing a refractor it's important to buy the best you can afford. The cheapest refractors have poor-quality lenses, which are often badly aligned, too. This results in images with distortion around the edges, and coloured fringes which you want to avoid. Refractors with the best-quality lenses are very expensive compared to reflectors, but you really do get what you pay for.

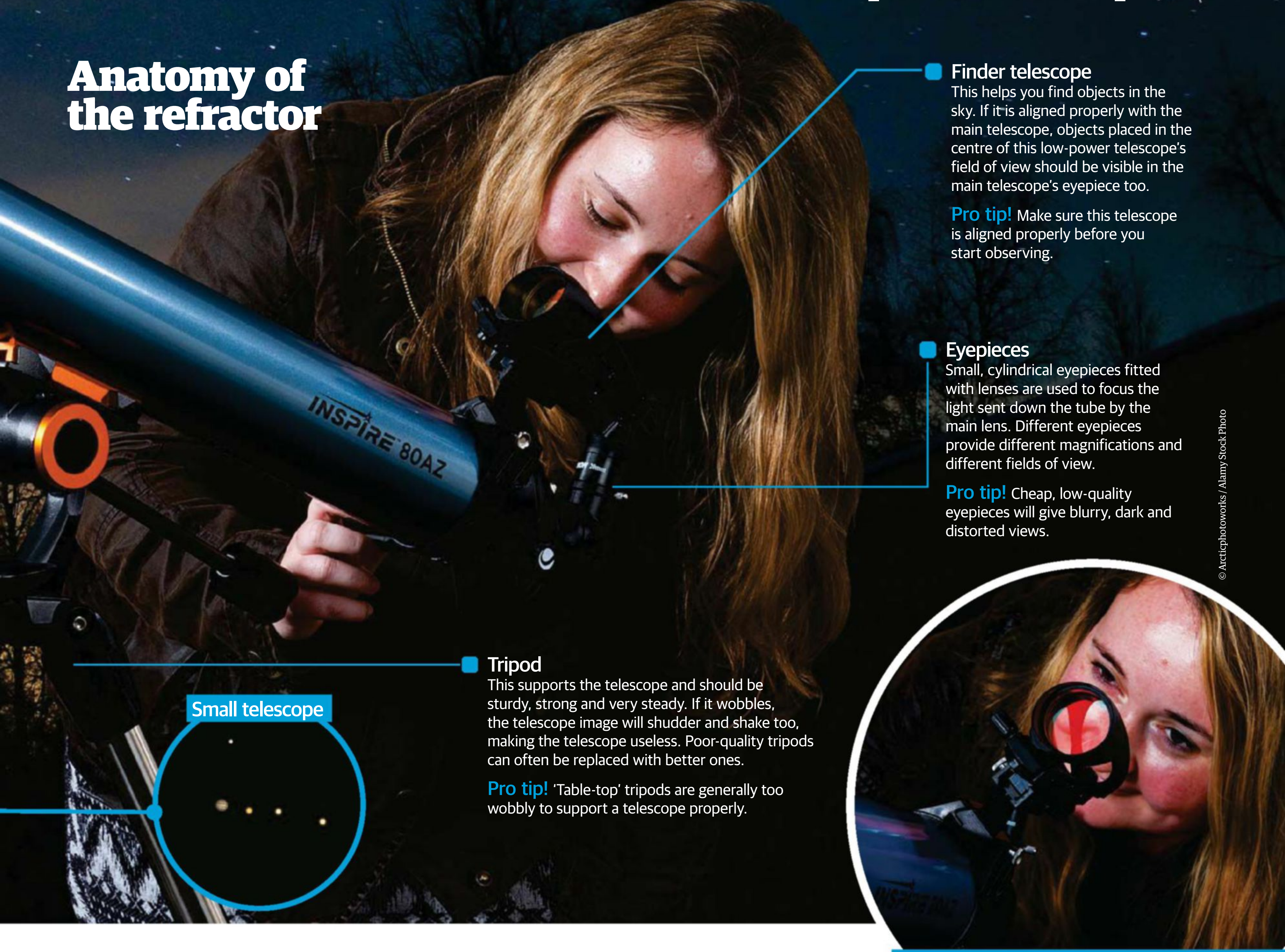
If you want to enjoy crisp, detailed views of Saturn's rings, the cloud systems of Jupiter and the surface features of Mars, then a refractor is the telescope for you. It will provide much better views of those objects than a reflector of equal, or even larger, aperture. However, refractors do not perform as well as reflectors when turned towards the 'faint fuzzies', such as galaxies and nebulae. If you are wanting to observe famous objects such as the Andromeda Galaxy and the Orion Nebula then a refractor might not be your best choice.

Modern refractors come on a wide variety of mounts, but it's important to note that all refractors are supported by tripods. As with any telescope, it's important to pick a refractor mounted on a stable, steady tripod or the image you see looking through it will jump around so much it will be useless. Many of the 'budget' refractors available are actually of quite good quality optically, but are let down by the poor-quality tripods they come supplied with. Small 'table top' tripods are particularly useless, and telescopes that come with those are little better than toys. However, a budget refractor's poor tripod can often be replaced with a good photographic tripod.

Refractors on simple alt-azimuth mounts are essentially 'point and look' telescopes - you just move

> "High-quality refractors remain the popular telescope for astronomers wanting to enjoy detailed views of the Moon and planets"

Anatomy of the refractor



Finder telescope
This helps you find objects in the sky. If it is aligned properly with the main telescope, objects placed in the centre of this low-power telescope's field of view should be visible in the main telescope's eyepiece too.

Pro tip! Make sure this telescope is aligned properly before you start observing.

Eyepieces
Small, cylindrical eyepieces fitted with lenses are used to focus the light sent down the tube by the main lens. Different eyepieces provide different magnifications and different fields of view.

Pro tip! Cheap, low-quality eyepieces will give blurry, dark and distorted views.

Tripod
This supports the telescope and should be sturdy, strong and very steady. If it wobbles, the telescope image will shudder and shake too, making the telescope useless. Poor-quality tripods can often be replaced with better ones.

Pro tip! 'Table-top' tripods are generally too wobbly to support a telescope properly.

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the tube up and down and from side to side until it's pointed roughly towards what you want to look at, then align the telescope more accurately using a small 'finder scope' mounted on the main tube. More complicated mounts allow you to find objects in the sky by first aligning the telescope with the Pole Star, and then turning dials on the mount until the telescope is pointed at a specific set of co-ordinates in the sky. Many modern refractors are mounted on computerised GoTo mounts, which make them very easy to use. After aligning the telescope on the Pole Star, and then on several additional 'guide stars', you enter the date and your location into the computer, then select an object from the telescope's own database by scrolling through various menus. The telescope then finds that object in the sky for you, slewing around until the object is centred in its eyepiece. Entry-level refractors are easy to assemble and maintain. Unlike a reflector, refractors don't need aligning or collimating before every use. However, more advanced refractors, just like large reflectors, take a lot of setting up and aligning before they can be used.

Achromatic vs apochromatic

Which is right for me?

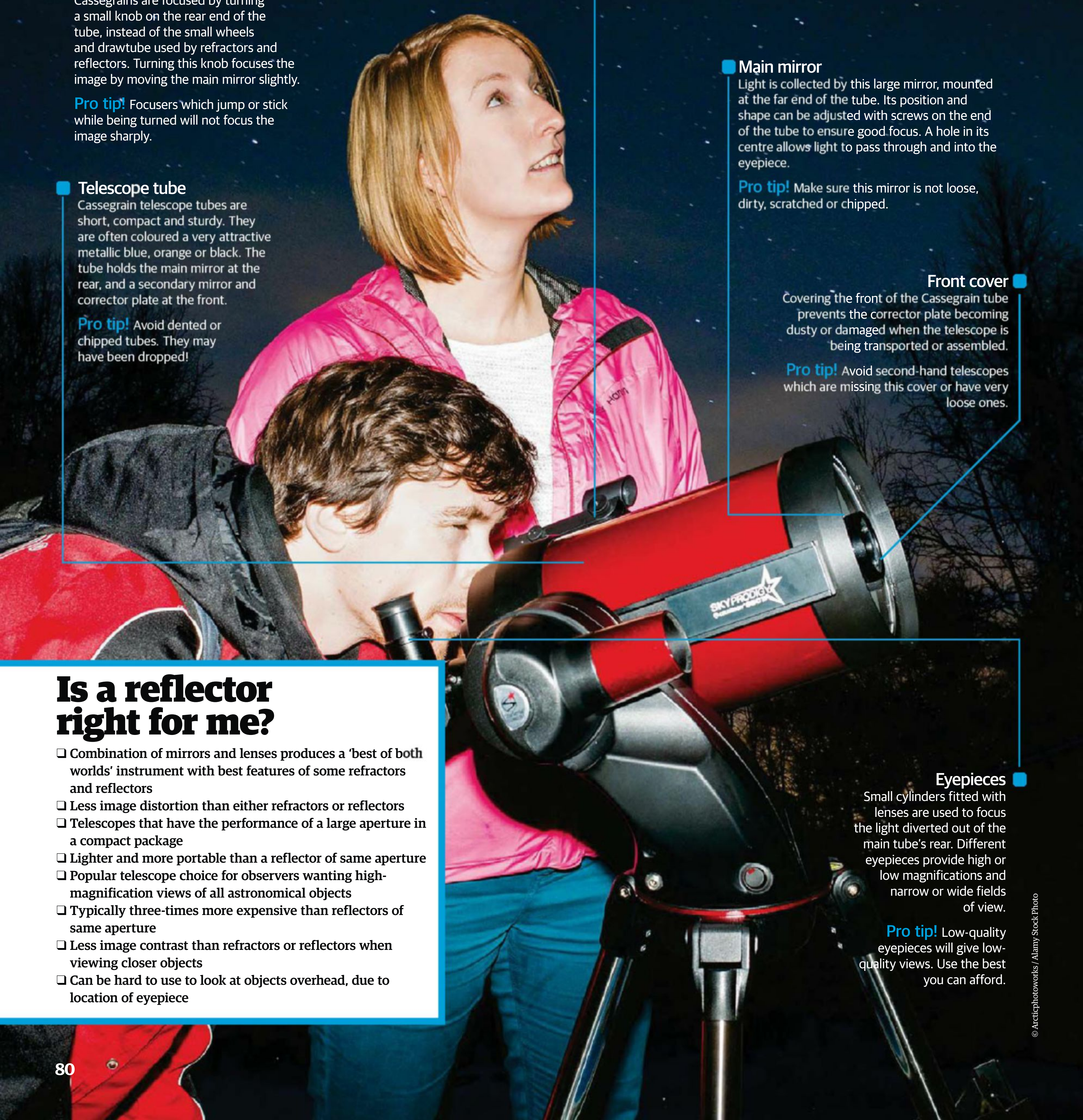
- Want a simple telescope to use
- Have a low budget for a small aperture
- Want a low-maintenance telescope
- Can tolerate colour fringing in cheaper achromatics
- Enjoy views of the Solar System

You should choose an achromatic

- Would prefer a refractor that doesn't suffer from colour fringing
- Have a high budget
- Enjoy views of the Solar System
- Are happy to own a high-maintenance telescope

You should choose an apochromatic

Anatomy of the Catadioptric



Focuser
Cassegrains are focused by turning a small knob on the rear end of the tube, instead of the small wheels and drawtube used by refractors and reflectors. Turning this knob focuses the image by moving the main mirror slightly.

Pro tip! Focusers which jump or stick while being turned will not focus the image sharply.

Telescope tube
Cassegrain telescope tubes are short, compact and sturdy. They are often coloured a very attractive metallic blue, orange or black. The tube holds the main mirror at the rear, and a secondary mirror and corrector plate at the front.

Pro tip! Avoid dented or chipped tubes. They may have been dropped!

Finder telescope
This low-power telescope helps align the telescope with the celestial pole. As most Cassegrains are computerised GoTo telescopes it is rarely used to help locate objects in the night sky.

Pro tip! Align this telescope on a distant tree or object during daylight to save time after dark.

Main mirror
Light is collected by this large mirror, mounted at the far end of the tube. Its position and shape can be adjusted with screws on the end of the tube to ensure good focus. A hole in its centre allows light to pass through and into the eyepiece.

Pro tip! Make sure this mirror is not loose, dirty, scratched or chipped.

Front cover
Covering the front of the Cassegrain tube prevents the corrector plate becoming dusty or damaged when the telescope is being transported or assembled.

Pro tip! Avoid second-hand telescopes which are missing this cover or have very loose ones.

Eyepieces
Small cylinders fitted with lenses are used to focus the light diverted out of the main tube's rear. Different eyepieces provide high or low magnifications and narrow or wide fields of view.

Pro tip! Low-quality eyepieces will give low-quality views. Use the best you can afford.

Is a reflector right for me?

☐ Combination of mirrors and lenses produces a 'best of both worlds' instrument with best features of some refractors and reflectors
☐ Less image distortion than either refractors or reflectors
☐ Telescopes that have the performance of a large aperture in a compact package
☐ Lighter and more portable than a reflector of same aperture
☐ Popular telescope choice for observers wanting high-magnification views of all astronomical objects
☐ Typically three-times more expensive than reflectors of same aperture
☐ Less image contrast than refractors or reflectors when viewing closer objects
☐ Can be hard to use to look at objects overhead, due to location of eyepiece

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The Catadioptric

A bit more costly, they combine the best bits of reflectors and refractors to give wonderful views

It's a dusty old astronomy joke: what do you get if you cross a refractor with a reflector? A cat. No, not the animal; 'Cat' is short for 'catadioptric', a type of telescope that combines the optical systems and hardware used in both 'old fashioned' telescopes to create something totally different and new.

In effect, a catadioptric is a long, large-aperture reflector that has been put in the Death Star's trash compactor and squashed and scrunched up into a shorter, stubbier tube, with some lenses put in to make it perform even better.

You can always spot a 'Cat' at a star party or in a telescope shop. They look like shiny metal barrels, often coloured a striking metallic blue or orange, mounted on the top of very sturdy-looking tripods. And they're usually surrounded by a crowd of adoring stargazers.

Catadioptrics are now the telescope of choice for many serious observers and astrophotographers. Their complicated optical systems mean they suffer from less image distortion than either refractors or reflectors, and when packed away they take up less room in the back of a car than either a large refractor or reflector - useful for trips to dark skies.

However, catadioptrics aren't perfect. They are expensive, typically three-times more expensive than reflectors of the same aperture, so the high-end models are beyond the budgets of most people wanting to buy their first telescope. Smaller, more modest models are available, but for the money they cost you might as well buy a larger refractor or reflector.

They also offer views of very bright objects, such as the Moon, that have less contrast than refractors or reflectors. Like standard reflectors, they are more suitable for deep-sky observers than lunar observers.

Another potential problem for a Catadioptric buyer to consider is that they can be hard to use to look at objects overhead, due to the location of their focuser and eyepiece at the rear end of the tube. Looking at an object high in the sky through a 'Cat' often means having to bend down, or sometimes even kneel on the ground, to look into the eyepiece. But 'Cat' owners put up with that for the amazing views they enjoy through their telescopes.

There are two main types of Catadioptric. The 'Schmidt-Cassegrain' is the most common type, and incorporates a large primary mirror, a smaller secondary mirror, and a correcting plate lens. Light passes down the tube, through the corrector plate, reflects off the primary mirror and goes back up the tube, where it is reflected downwards again off the secondary mirror. The light then passes through a hole in the centre of the primary mirror into the telescope eyepiece.

The 'Maksutov-Cassegrain' design is very similar to the Schmidt-Cassegrain in that it uses a combination of mirrors and lenses to collect light and form an image. However a 'Mak' uses a much more highly curved corrector plate lens at the front of the tube to help focus the incoming light onto the main mirror. Like refractors, the optical qualities of Maksutovs make them more suitable for observing the Moon and Solar-System objects than deep-sky objects.

All 'Cat' telescopes are mounted on very sturdy tripods. Almost all are now GoTo telescopes with built-in computers, which once the telescope is properly aligned with the pole can be pointed at any object in the sky simply by selecting its name or details with a handset.

There is no such thing as a 'perfect telescope', but many experienced observers say that if you're looking for a telescope that will give you great views of anything and everything in the sky, is reasonably portable, and will require very little maintenance, it's hard to beat a 'Cat' - if you can afford one!

> "Catadioptrics are now the telescope of choice for many serious observers and astrophotographers"

Schmidt-Cassegrain vs Maksutov-Cassegrain

Which is right for me?

- **You want a low-maintenance telescope**
- **Portability is essential**
- **You want to observe Solar-System objects and bright deep-sky objects**

You should choose a Maksutov-Cassegrain

- **Have a low budget**
- **Interested in observing all kinds of targets besides open clusters and large patches of the Milky Way**
- **Aren't bothered about purchasing corrector lenses to reduce coma**
- **Require portability**

You should choose a Schmidt-Cassegrain

Telescope mount
Cassegrains are mounted on top of their tripods in various ways. Some sit inside a fork-shaped cradle, others on an equatorial 'wedge'. Others are mounted on a single arm connected to a computerised GoTo system.

Pro tip! Driven and computerised mounts need electricity to work - either batteries or connection to a power source.

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How to...

Capture the Leonid meteor shower

One of the most reliable and potentially impressive of all the regular meteor showers. Here's how to see it at its best...

You'll need:

✔ Warm clothing
✔ Red torch
✔ Notebook for recording

There are several meteor showers to be seen over the course of the year, some, like the Perseids, are well known. Others, such as the Quadrantids, are less so. The Leonids occur in November and usually put on a good show, and they have been known to 'storm'. Although it is unlikely we should see such an incredible event this year, a Leonid storm has occurred in living memory. In 1966 the sky was full of falling stars, a breath-taking spectacle! This storming of the Leonids occurs every 33 to 34 years, and although the shower in 1999 was not as spectacular as the one in 1966, it was still impressive. Even in between these peaks this meteor shower can give a very good show, and 15 to 20 shooting stars per hour can be seen. There are many factors which govern just how many meteors can be seen on any given night, however. Atmospheric condition for one will make a large difference. If it's cloudy then your chances of seeing meteors drops dramatically, but a mist and dust can also have an effect. The other important factor is the position of the Moon. Because the Moon is usually very bright, it can 'drown out' fainter objects, including meteors. No Moon in the sky is therefore much better for seeing shooting stars. This year, the Moon will not be a problem, as it will be approaching its 'new' position and not be visible for most of the night.

All meteor showers have a radiant point, where they all appear to emanate from a single point in the sky. Where this point is located gives us the notion of naming a particular shower. In this case, the radiant point can be found in the constellation of Leo, where all the meteors in the Leonids seem to appear. However, looking at this point is not, in fact, the best way to appreciate them, as the meteor streaks will appear very short here. It is best to look around 30-degrees away from the radiant, but looking anywhere in the sky should work. It is important to be comfortable and warm when on a meteor watch along with having patience, so stay out as long as you can and your patience will surely be rewarded. Make a note of the time, direction and brightness to be sure that you have spotted a Leonid, as there are other occasional meteor events that are not connected with the shower.

> "The Leonids occur in November and usually put on a good show"

Tips & tricks

Observe at the peak

The Leonids build up over the month of November and their peak is usually on the 18 November.

Get dark adapted

You will improve your chances of spotting fainter meteors if you eyes are fully dark adapted. This can take between 20 and 30 minutes.

Use a red torch

A red torch is essential to help you make notes and not affect your dark adaption.

Aim to observe at or after midnight

The hours after midnight are the best to spot the Leonids, as the Earth is rotating into the meteor stream.

Shield yourself from light pollution

Get to a dark sky site, if you can, to watch the shower. It will improve your chances of seeing the shooting stars.

The Leonids at their best

The Leonids, along with other such showers, are rated by their Zenith Hourly Rate (ZHR).

Watch tiny comet fragments shoot across the sky

Debris from Tempel-Tuttle will illuminate the skies, peaking on 18 November

The ZHR of a meteor shower is an approximation of the number of meteors you would likely see if you were under a completely dark, clear sky at the peak of the shower, with the radiant point directly overhead. This seems totally unrealistic, but it is, in fact, the best way of estimating the strength of any given meteor shower. Realistically though, conditions such as this don't happen, so you must make allowances. Meteor showers can be unpredictable and you may see much less (or even more) than the ZHR.

Send your photos to
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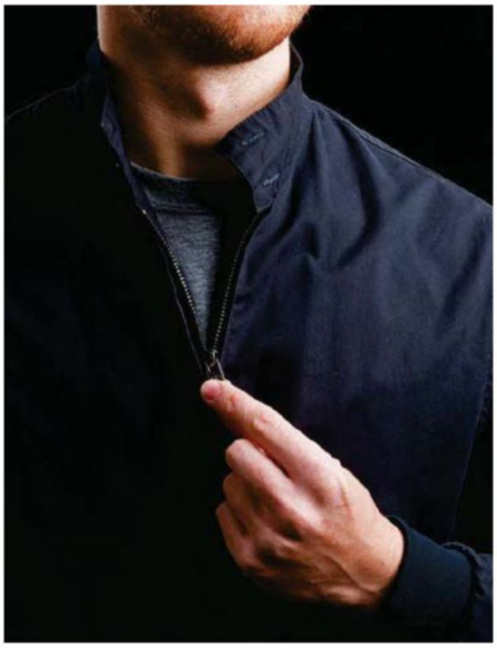
1 Know when the meteors are at their best

Check when the peak of the shower is expected, however, go out a day or two either side of this too. You may get a surprise!

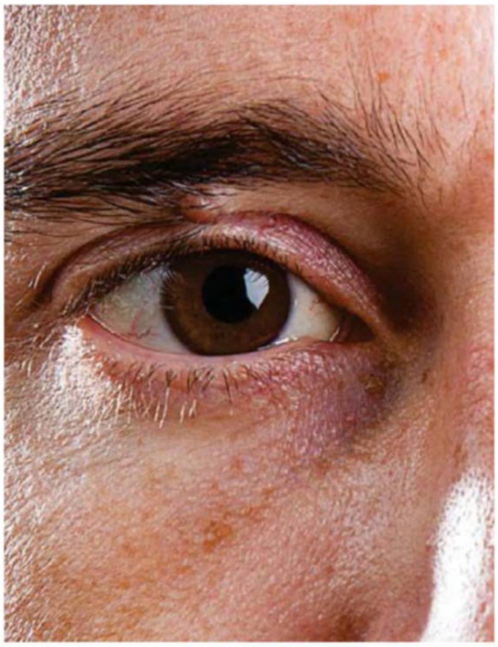


2 Comfort is a must

You're going to be observing at low temperatures, so you should ensure that you're wrapped up warm and sitting comfortably whilst on meteor watch.

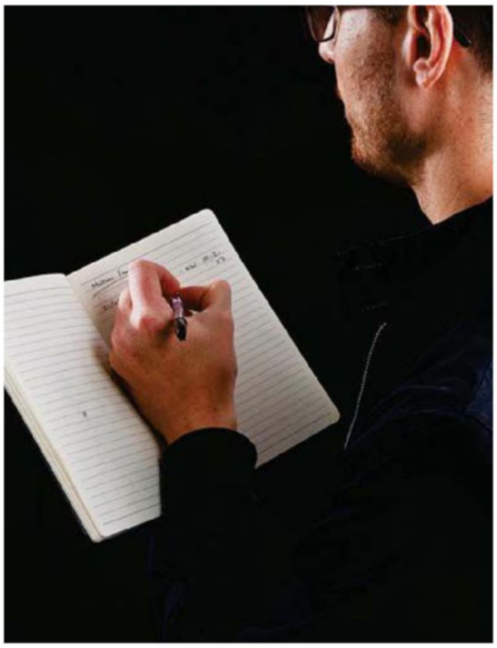
3 Observe after midnight

The sky will become darker after midnight as many turn in for the night and the Sun is way below the horizon, making the faintest of meteors visible.



4 Let your eyes adapt to the dark

It can take between 20 and 30 minutes to get fully dark adapted, so factor this into your observing. If you need to use a sky map or find your way around in the dark, then use a red torch.



5 Record your observations

Once you've seen a meteor, make a note of its direction and the time you observed it. Again, to ensure that you preserve your night vision when writing, you should use a red torch.

6 Stay up late!

Stay out for as long as you can in order to increase your chances of seeing the Leonids. You should avoid coffee to stay awake, since this will impair your observing ability.

The Andromeda Galaxy (M31), with dwarf galaxy M110 (bottom right)

Deep sky challenge

The Andromeda Galaxy and autumn's nebulae and star clusters

As the leaves fall from the trees, the night sky brings a wealth of well-known and less familiar objects for you to enjoy

Longer nights mean that those of us armed with binoculars or a telescope can spend more time getting to know amazing sights. This season brings us galaxies and star clusters on which to feast your eyes. There are objects which are easy to see and those that are more challenging, especially for a small telescope. There are famous galaxies to be seen, such as the Andromeda Galaxy - also known as Messier 31 - but don't overlook the less well-known objects, as these can prove just as interesting and rewarding. In the case of the Andromeda Galaxy you will need a low-power, wide-field eyepiece to see the whole structure, or even just binoculars, whereas the globular star cluster will need more power to help resolve the stars. If you want to see the planetary nebula well, then an OIII filter will assist with picking out the fainter, more diffuse gases not easily picked out with just optical aid alone.

1 Great Pegasus Cluster (Messier 15)

This lovely globular star cluster looks great at medium magnification, glowing at a magnitude of 6.2 thanks to its dense population of stars. The brightest member stars in Messier 15 have a magnitude of 12.6, which can easily picked up using binoculars and small telescopes. Unless you are using an aperture of at least 6-inches, Messier 15 appears as a fuzzy patch of light in Pegasus.

2 Blue Snowball Nebula (NGC 7662)

Known as the 'Blue Snowball', for obvious reasons once you see it, this amazing nebula is best observed in large apertures with an OIII filter to pick out its distinct blue-green hue. However, with an aperture of 8.6, medium instruments will reveal a round ball, around 17-inches in diameter, while smaller scopes at high magnification make a very bright round ball.

3 NGC 7686

This moderate-sized open star cluster is a treat at medium power, even through a small telescope. It's an easy target for binoculars with its magnitude of 5.6, containing 80 stars of white-blue and yellow-white hues.

4 Messier 110

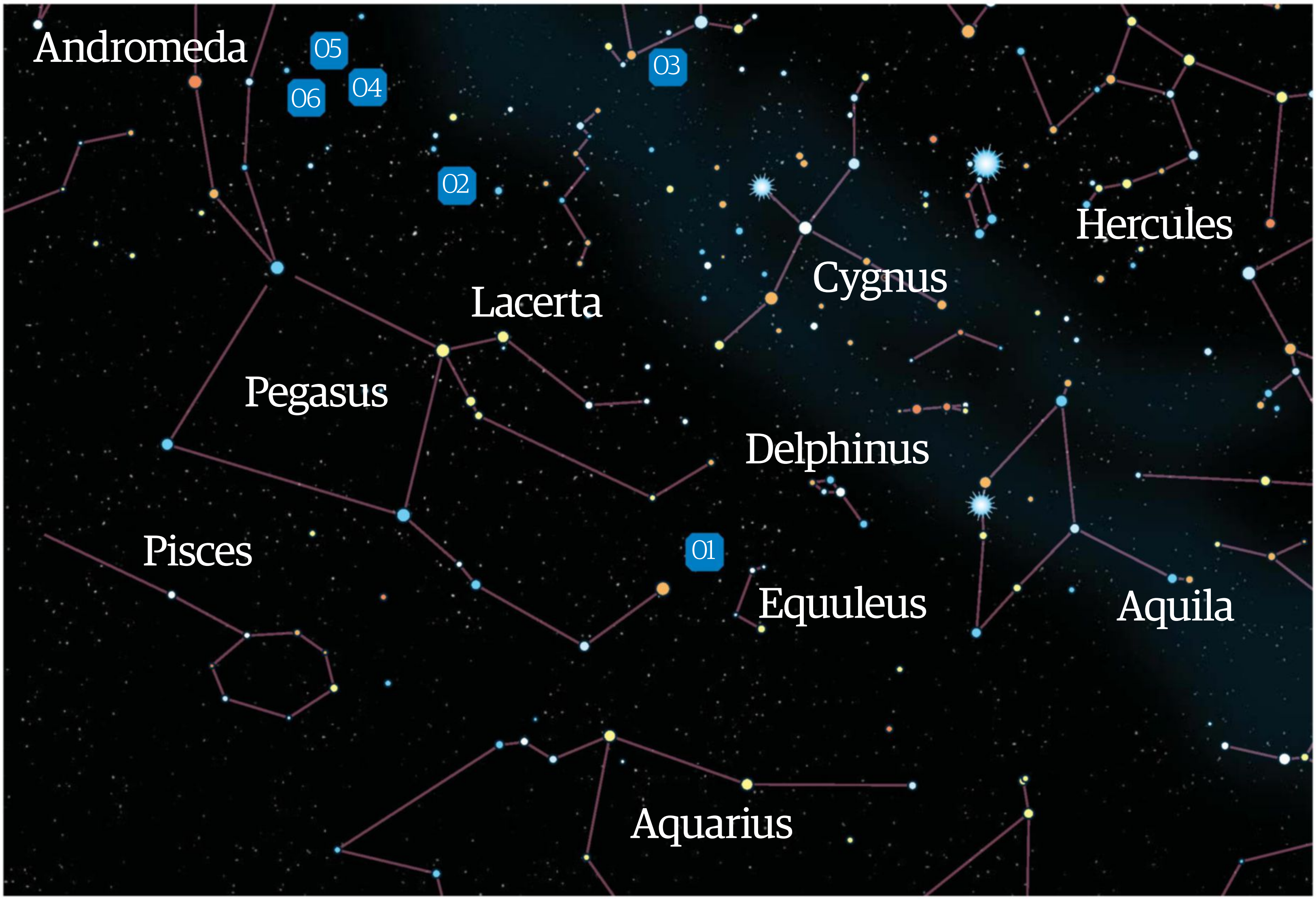
Located in the same field of view as the Andromeda Galaxy, this object is smaller to see, but an island universe in its own right. To see it in modest-sized telescopes, you will require exceptionally clear, dark skies. Observers will spot a faint, diffuse patch of light through apertures of 3-inches, while 8-inch telescopes will pick out a larger oval and a marginally brighter core.

5 Andromeda Galaxy (Messier 31)

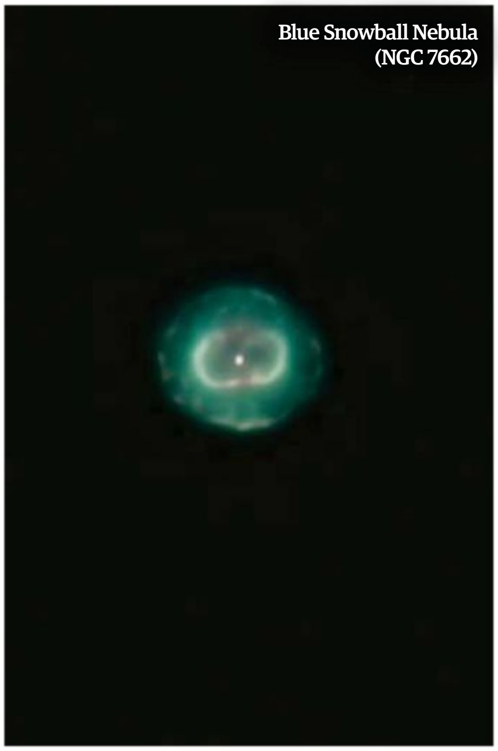
Probably the most famous galaxy in the night sky, it is best seen at low power or with binoculars. It's easy to find in the night sky, lying in the vicinity of two prominent asterisms: the Great Square of Pegasus and Cassiopeia's W. Through 10x50 binoculars, you can pick out an oval-shaped cloud with a bright nucleus, while even larger apertures will pick out spiral arms and the spiral's satellites.

6 Messier 32

This galaxy is a little harder to see, as it is tucked behind the bigger, brighter M31. Designated NGC 221 or Le Gentil, telescopes reveal Messier 32 as a diffuse ball of light with a bright core that's surrounded by a faint, diffuse halo.



Messier 15


Blue Snowball Nebula (NGC 7662)

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How to...

Collimate your reflector telescope

To get the best out of your Newtonian, it's important that the primary and secondary mirrors are properly aligned. Here's how to do it...

You'll need:

- ✔ Newtonian reflector telescope
- ✔ Collimating eyepiece

Many of us have, or have access to, a Newtonian reflecting telescope. They use mirrors, rather than a lens, to gather and focus the light. In order to work well, the mirrors need to be lined up correctly with a process known as collimation, which is best carried out in daylight. It can be a little scary the first time you attempt to collimate a telescope, but if you follow a few simple guidelines then you'll find it is really quite straightforward.

You will need a collimating eyepiece to carry out the procedure correctly. You can purchase one of these from any good telescope dealer, or you can make one yourself using an old 35mm film canister - if you can find one! With a strong needle, pierce a hole in the bottom of the canister dead centre, and you've got your collimating eyepiece. The canister is placed in the empty focuser of your telescope; it should be a fairly tight fit. The hole, which you look through, keeps your eye centred on the optical axis of the telescope. First of all though, you need to check that the primary or main mirror is sitting correctly in the telescope tube. Look down the open end of the telescope and see if the secondary mirror appears concentric with it, in the centre of the main mirror. If it isn't, you will need to adjust the main mirror using the collimating screws at the back of the mirror. A word of caution here: only make small adjustments of, at most, a quarter of a turn on each screw, and check what difference it has made after each and every turn. In other words, take things very slowly and steadily. If you happen to overdo it, it's much easier to backtrack a small adjustment than a large one! Once you are happy that your primary mirror is correctly adjusted, turn your attention to the secondary. Look through the collimating eyepiece and see if the reflections you can see are concentric. If not, then you need to adjust the secondary mirror. Go slowly, and follow what you are doing through the eyepiece. If it looks worse, turn the screw the other way. The screws will be located on top of the 'spider', the device that carries the secondary mirror. If you take your time and are methodical, you will soon have your telescope in perfect collimation, which will mean nice sharp stars.

Tips & tricks

Check your telescope regularly

It's a good thing to check your telescope's collimation on a regular basis. Of course, how often you do this depends on how much you use your instrument.

Alter your instrument gently

When carrying out the process of collimation, you should take your time and do make any changes to your optical system gently and with a lot of care.

Understand your telescope's mechanisms

Locate the adjusting screws and understand how they work. For example, are they slotted or hexagonal headed?

Take care when adjusting mirrors

When adjusting the secondary mirror, have the tube tilted to 45 degrees or less. That way, if you drop the screwdriver it won't fall on the main mirror!

Use a suitable eyepiece

To use your collimating eyepiece, put it in the focuser with the blank end, with the small hole nearest your eye. You will need to be able to see clearly though the hole.

Get great observations with a little tweaking

Good collimation is about being methodical. The benefit will be seeing really round, sharp stars when looking thought an eyepiece or imaging...

See the stars exactly as they should be

Good collimation will help keep the skies in focus

If the collimation of your telescope is poor, stars can take on the appearance of comets! This will have the effect of blurring the image, even at best focus. This in turn can mean not being able to split close double stars or seeing fine detail on the surface of the Moon or planets. Collimation is a vital part of telescope maintenance and helps keep your instrument performing at its best. The beauty of it is that you can do it yourself, as it is straight forward, and once you are used to doing it, it only take a few minutes.

Send your photos to
space@spaceanswers.com

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1 Ask yourself: does it need doing?

Place a bright star in the middle of the field of view and defocus the telescope. If the star looks like a doughnut, then your scope is suitably collimated.

2 Pay attention to the main mirror

Look down the front of your telescope. If the main mirror is not concentric (lined up) with the tube and spider, then start making adjustments.

3 Slot your collimating eyepiece into the focuser

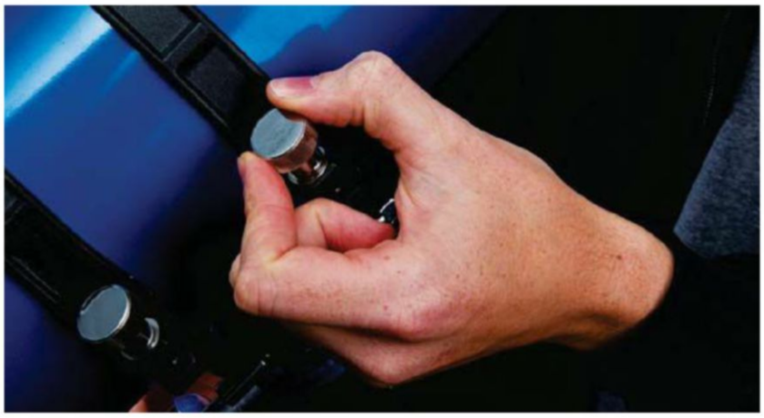
Place the eyepiece and look through, taking note of where the tube and spider are with respect to the main mirror. Is everything aligned properly?

4 Pay attention to your secondary mirror

If your main mirror appears off to one side in the secondary mirror, you will need to adjust the secondary. Be sure to do this with care.

5 Tilt the tube

Ensure that you tilt your telescope's tube by 45 degrees or less to prevent screwdrivers or wrenches falling on the primary mirror and damaging it.



6 Tighten the screws

Once you are happy that the mirrors are aligned make sure that all screws are tightened, but are not too tight.

The Northern Hemisphere

Now in the middle of the autumn, the darkness of the skies bring with it some astronomical favourites

Circumpolar constellations Cassiopeia (the Queen) and Cepheus (the King) lie in the dusty path of the Milky Way, offering not just a rich star field but impressive deep-sky objects. In particular, the Owl Cluster (NGC 457) is easy to pick out with decent binoculars, its 75 to 100 bright stars forming the shape of an owl with spread wings, while its bright double star Phi Cassiopeiae forms the celestial bird's eyes. Among Cassiopeia's splendour of star clusters, double star Alpha Cassiopeiae can easily be split into a stellar pair, resolving a bright yellow primary and faint blue secondary and providing delightful view for observers.

Use the constellations of Pegasus, Aquarius and Pisces and you'll be able to locate Cetus (the Sea Monster), which contains the remarkable variable star Mira, as well as a wide selection of galaxies.

Using the sky chart

This chart is for use at 10pm (BST) mid-month and is set for 52° latitude.

01 Hold the chart above your head with the bottom of the page in front of you.

02 Face south and notice that north on the chart is behind you.

03 The constellations on the chart should now match what you see in the sky.

Magnitudes

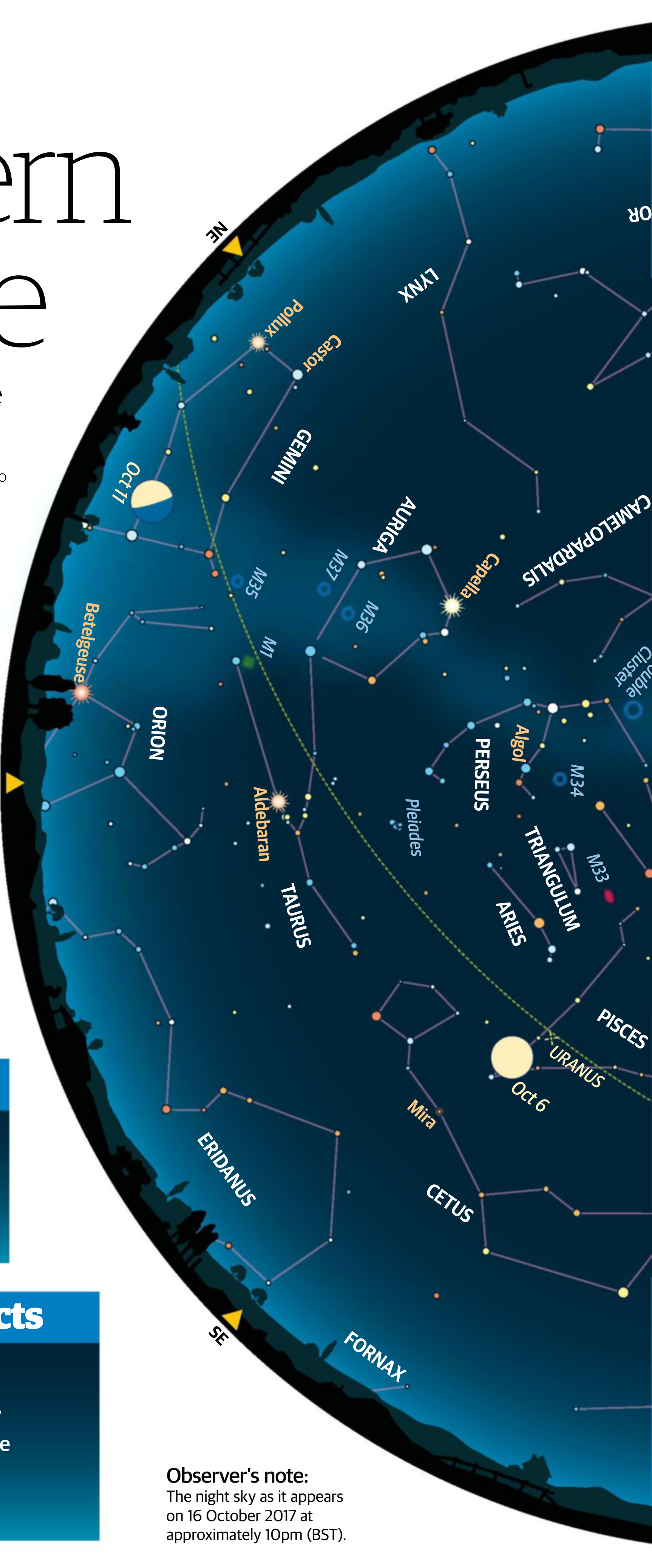
- Sirius (-1.4)
- -0.5 to 0.0
- 0.0 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- Fainter
- Variable star

Spectral types

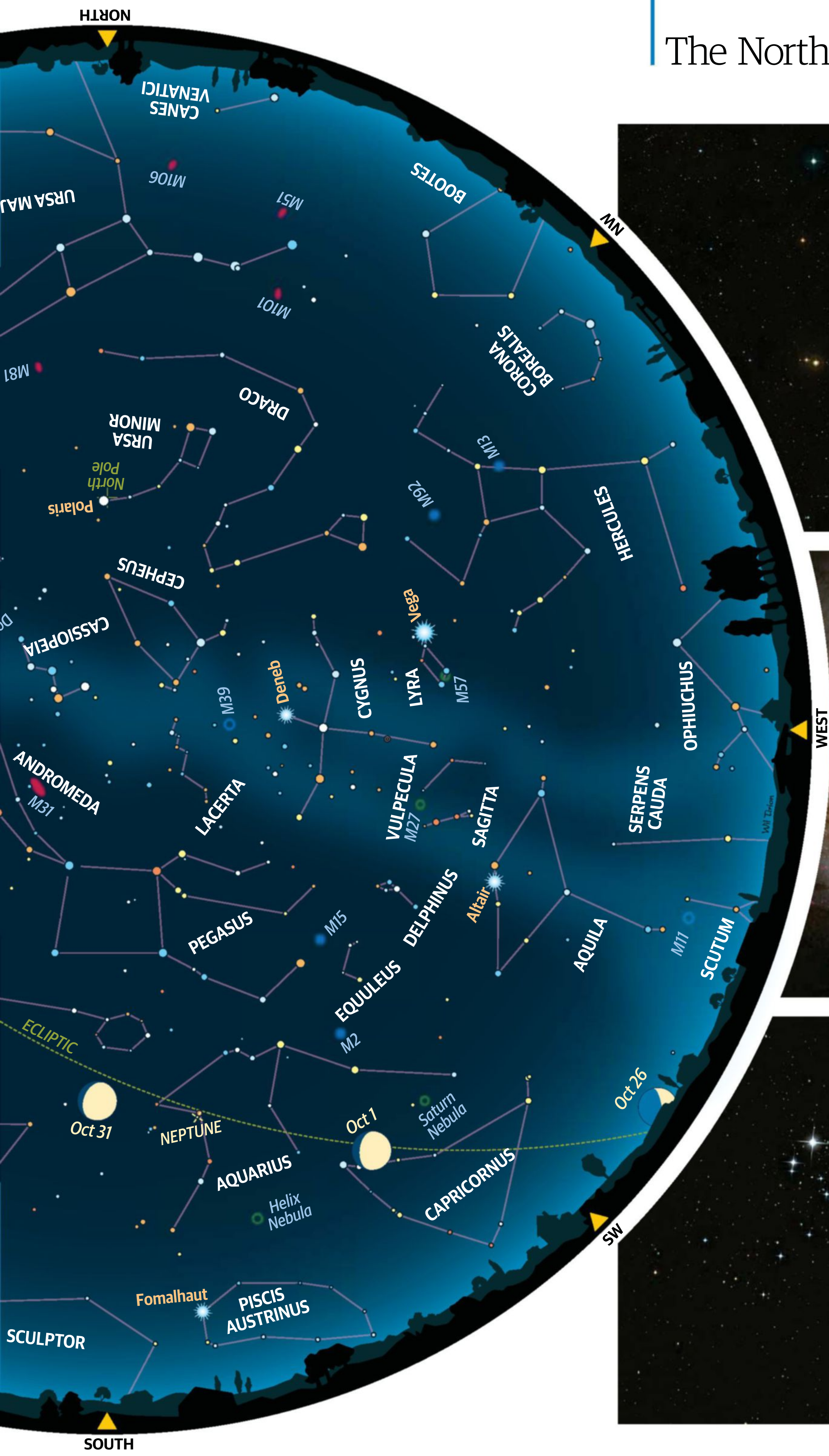
- O-B
- A
- F
- G
- K
- M

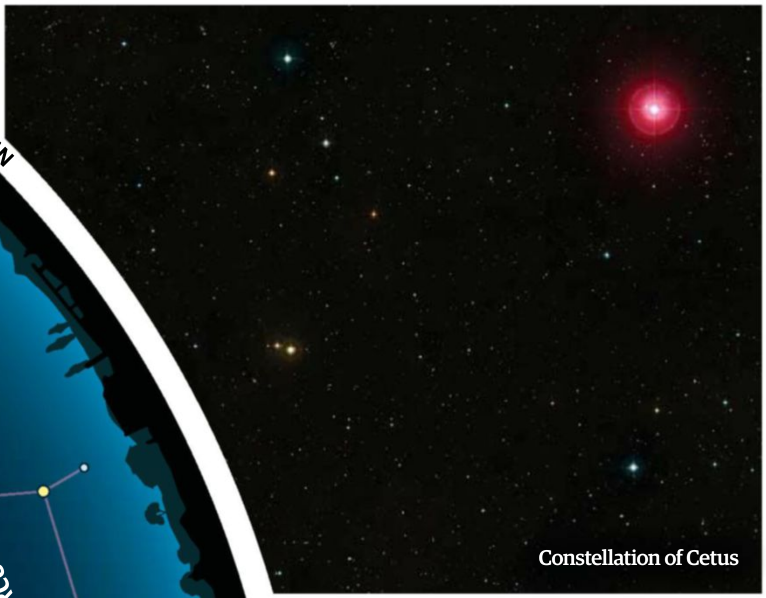
Deep-sky objects

- Open star clusters
- Globular star clusters
- Bright diffuse nebulae
- Planetary nebulae
- Galaxies



Observer's note:
The night sky as it appears on 16 October 2017 at approximately 10pm (BST).




Constellation of Cetus

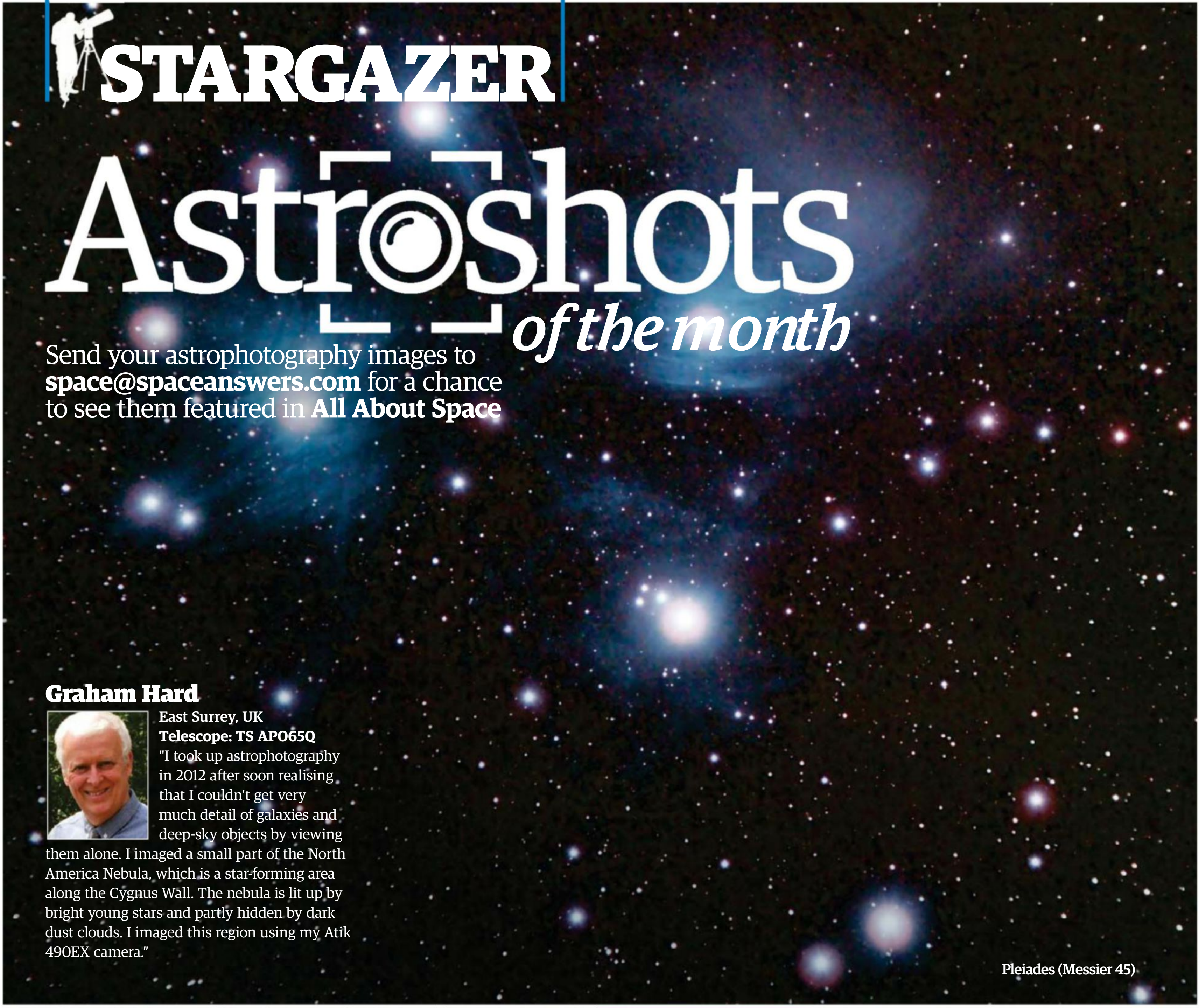
Messier 77

The Owl Cluster (NGC 457)

© Wil Tirion; DSS2/ESO; NASA, ESA & A. van der Hoeven; Gabbygall

Astroshots of the month

Send your astrophotography images to **space@spaceanswers.com** for a chance to see them featured in **All About Space**



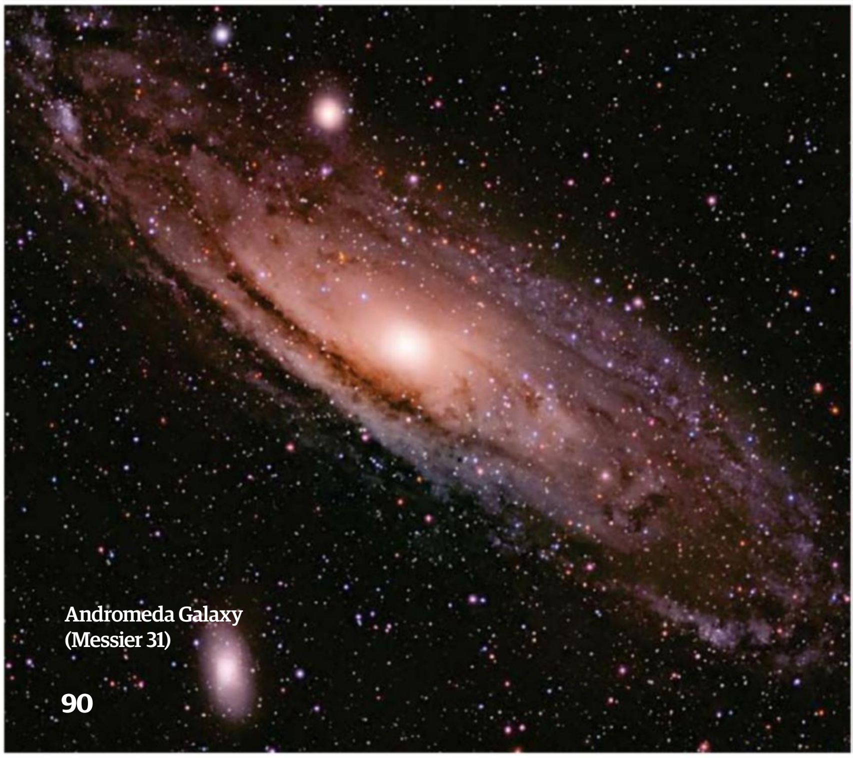
Pleiades (Messier 45)

Graham Hard

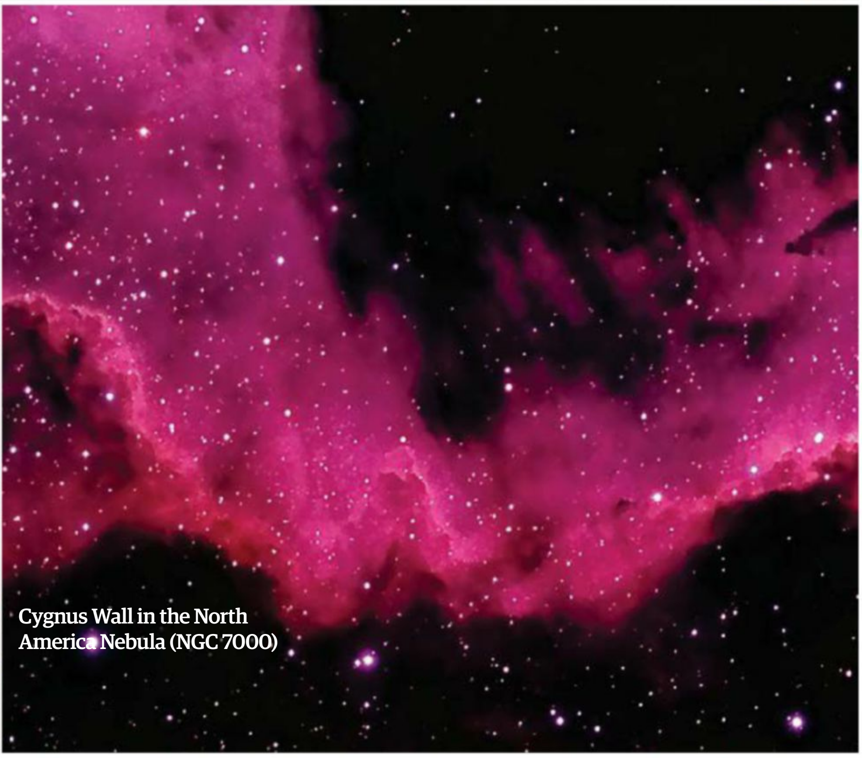
East Surrey, UK

Telescope: TS APO65Q

"I took up astrophotography in 2012 after soon realising that I couldn't get very much detail of galaxies and deep-sky objects by viewing them alone. I imaged a small part of the North America Nebula, which is a star-forming area along the Cygnus Wall. The nebula is lit up by bright young stars and partly hidden by dark dust clouds. I imaged this region using my Atik 490EX camera."



Andromeda Galaxy (Messier 31)

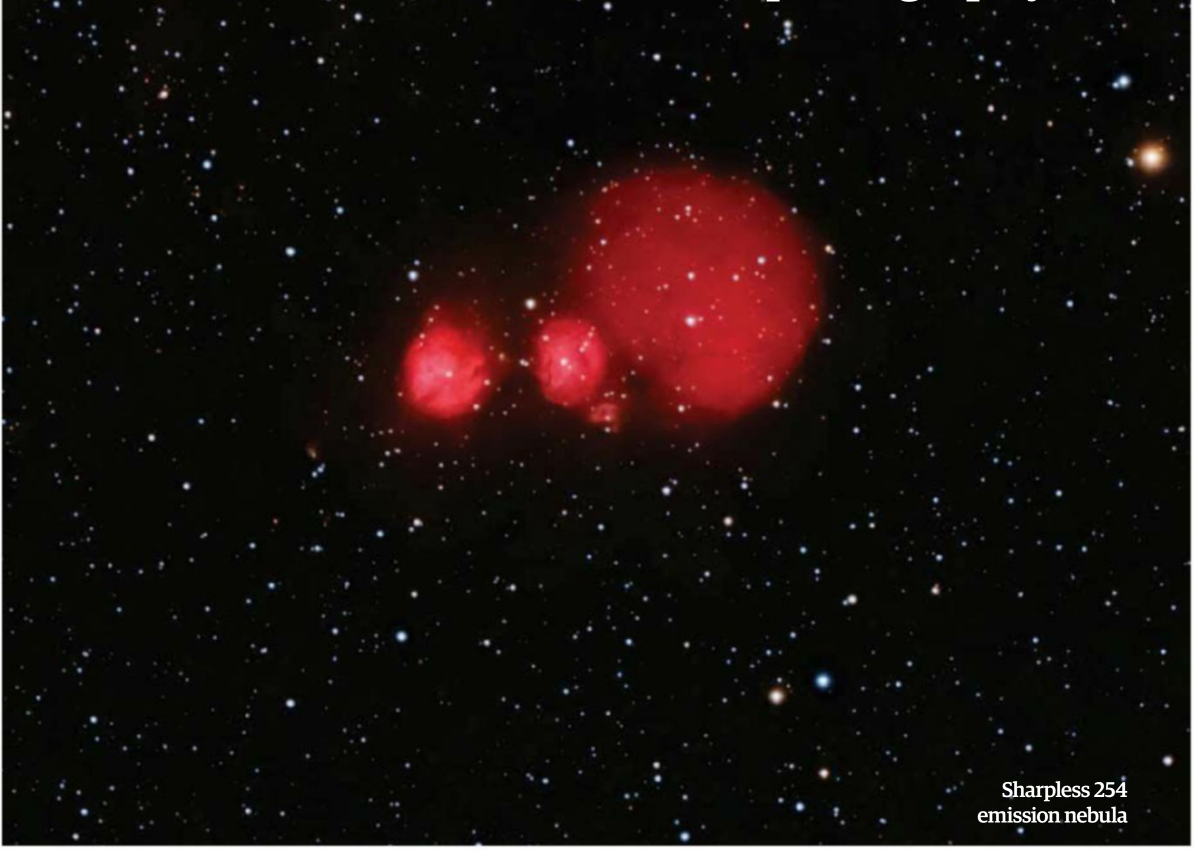


Cygnus Wall in the North America Nebula (NGC 7000)

Jeff Johnson

Las Cruces, New Mexico
Telescope: Takahashi FS-60C refractor

"I have a long love of astronomy and have observed the night sky for many years with binoculars and a telescope from the age of ten. I did my first 'real' astrophotography in 1996, when I used a 35mm SLR (film) camera to take photos of Comet Hyakutake. I took a tripod out into the desert here in Las Cruces and just experimented with exposures. Later, I bought a ten-inch Dobsonian for viewing, and within a week was taking pictures through the eyepiece for fun. Within a few more weeks, I knew I wanted to get serious with astroimaging."



Sharpless 254 emission nebula

Boston 'Red Sox' eclipse

Crescent Moon and earthshine

Ronald Zincone

Richmond, Rhode Island

"Like many astroimagers, I began my hobby in astronomy at the basic level known as 'camera-on-tripod' wide-field celestial photography. I enjoy all forms of astrophotography - it is challenging and frustrating at times but also very rewarding! To be a serious astroimager, you must be prepared to sacrifice sleep, travel to dark-sky sites, be diligent, patient and enjoy hands-on learning.".

Send your photos to... @spaceanswers @ space@spaceanswers.com

The Evostar-90 can also be used for terrestrial observations

Sky-Watcher Evostar-90 (AZ PRONTO)

To go from looking at your TV to looking at the night sky has never been easier with this excellent starter telescope

Telescope advice

Cost: £259.00 (approx $350)
From: Optical Vision Ltd
Type: Refractor
Aperture: 3.54"
Focal length: 35.43"

Best for...

- Beginners
- Medium budget
- Planetary viewing
- Lunar viewing
- Bright deep-sky objects
- Terrestrial viewing

Winter has finally arrived, an astronomer's favourite time of the year. The nights are longer, the air is colder and beautiful scenes return in the form of Orion, Gemini and Canis Major. Now is the best time to utilise the long nights, and the Sky-Watcher Evostar-90 (AZ Pronto) is the best way to do that. This new range of Sky-Watcher telescopes take the old models, and modernise them with a new AZ Pronto alt-azimuth mount. This telescope is incredibly easy to assemble and use, so if you look outside the window and see that it's a clear night, you don't have to spend valuable time setting up a complex telescope. This is why it's ideal for an amateur astronomer, but it can also be suitable for high-power daytime terrestrial observations.

For the sake of simplicity, the telescope package contains the standard accessories necessary for the average observing session. Along with the prime telescope tube, tripod and accessory tray is a 6x30 finderscope, two Sky-Watcher Super eyepieces, a 90 degree erect image diagonal and a mount extension. The two eyepieces supplied have a 10mm and 25mm focal length, which when combined with the telescope provides a magnification of x90 and x36 respectively. These magnifications allow you to get a respectable field of view, which can bring the exciting celestial landmarks into view. For example, if you attach the 25mm eyepiece, an entire full Moon can fit in the field of view. Navigating to the full Moon may be a bit more trickier for the beginner at the start, as the mount of the telescope is comprised of an manual alt-azimuth mount. This mount will allow you to manually move the telescope horizontally and vertically using slow-motion cables. This requires a careful hand to navigate to a certain spot in the sky – particularly because of the flexible handles – especially when you attempt the harder-to-find deep-sky objects, but that comes with practice. When the celestial object has been centred into the field of view, it was quickly discovered that the tripod and mount combination give excellent stability and support.

This telescope has been primarily advertised as a 'Grab-and-Go' telescope, and it has lived up to the hype. The ease to assemble this lightweight telescope proved to be

> "It has been primarily advertised as a 'Grab-and-Go' telescope, and it has lived up to the hype"

quick and painless, which certainly helps when you may have a tight time frame to work with. The total weight of the telescope is close to six kilograms, which makes it incredibly easy to move around, and also means if you have to hike up a hill to get away from the light pollution of the suburbs, you will certainly be pleased you have this telescope. Preparing the telescope for observation should take only a matter of minutes, but there is a clear and concise instruction manual that includes diagrams to help you if there are any issues. We also recommend that you attach the mount extension at the same time, because although it is not essential, it raises the eyepiece so there is less crouching when observing objects closer towards the zenith – the point directly above the observer.

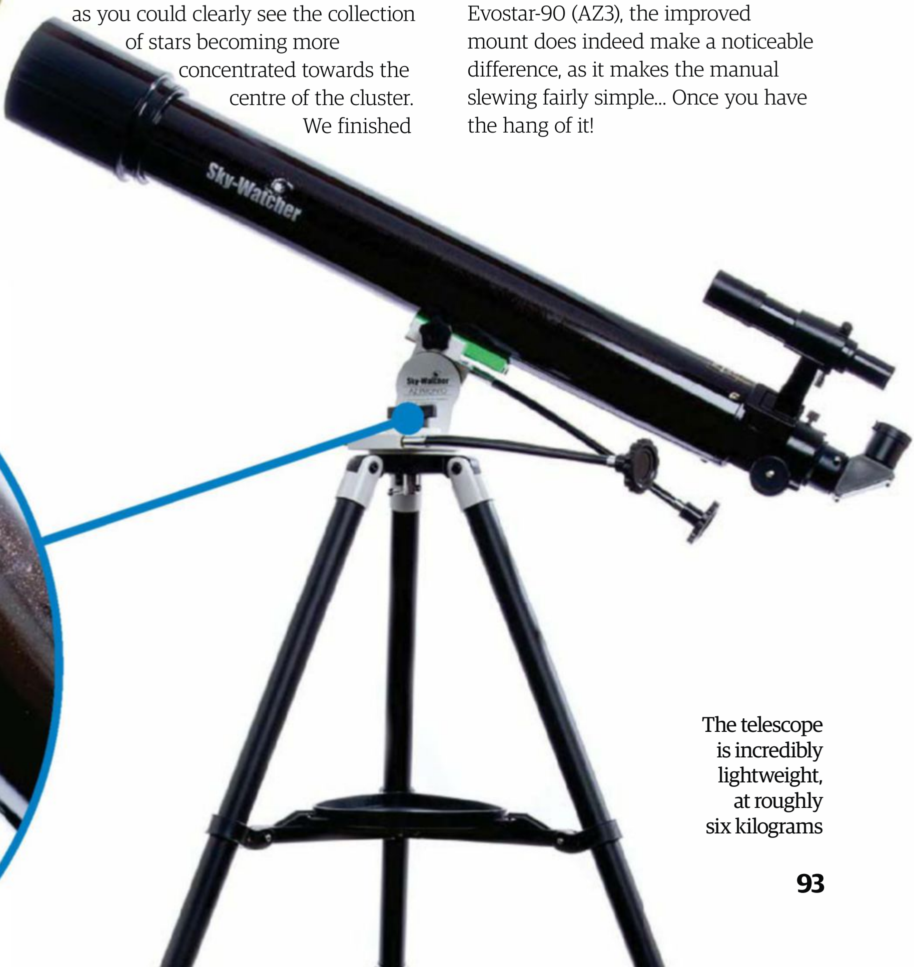
Once the telescope was ready for observing, we were excited to test out the famous Sky-Watcher optics. The optics of the telescope are considered the 'old' aspect of the telescope, as it uses similar refracting lenses as the Sky-Watcher Evostar-90 (AZ3). What makes the Sky-Watcher refractor optics so special is that they are made up of an air-spaced, two-element achromatic refractor. Normal refractors use the one single lens to bend the light, but this causes chromatic aberration, meaning that different coloured light doesn't converge at the same focus point. However, Sky-Watcher add a second lens to correct for this, meaning that all the colours converge at the same focal point, bringing the crispest and clearest views of the winter sky.

We put this to the test on an autumn night, where we started with the brightest star in the sky, Arcturus of the constellation Boötes. This star was flickering brightly at an apparent magnitude of -0.04, which made it the perfect starter star to locate within the field of view and focus upon. Using the 25mm eyepiece, Arcturus was centred and it revealed a wonderful twinkling view. The star was close to the horizon at the time, so the twinkling was due to the atmospheric interference. We decided to head more towards the zenith to attempt to view a more difficult celestial object. After a fair amount of manual slewing, we finally gazed upon the sights of M13, also known as the Great Cluster of Hercules, shining at a dimmer magnitude of 5.8. Once we arrived at M13 it was a spectacular sight using both the 10mm and 25mm eyepieces, as you could clearly see the collection of stars becoming more concentrated towards the centre of the cluster. We finished by observing the second-brightest star in the sky, which was Vega of the constellation Lyra, and its close companion the Epsilon Lyrae. Both views were great through the 10mm eyepiece, as Vega showed as a fine-white star with a slight-bluish hue, and we could also decipher the two stars of Epsilon Lyrae.

After sampling the new Sky-Watcher Evostar-90 (AZ PRONTO), the main point to take away was that this telescope is great value for the money. It would be perfect for a beginner, as it is a simple piece of equipment that has great light gathering capabilities. It can also be utilised for terrestrial viewing as well, but for the astronomer it does a great job of resolving many novice celestial objects. Even though it has similar optics as the cheaper Evostar-90 (AZ3), the improved mount does indeed make a noticeable difference, as it makes the manual slewing fairly simple… Once you have the hang of it!

The telescope is supplied with good quality 10mm and 25mm Sky-Watcher eyepieces

The newest feature of this telescope is the AZ Pr mount



The telescope is incredibly lightweight, at roughly six kilograms

WIN!

A CELESTRON INSPIRE 80AZ REFRACTOR

WORTH £179

Be inspired to explore the night sky with this lightweight and versatile instrument, courtesy of Tring Astronomy Centre

The Celestron Inspire 80AZ is equipped with fully-coated glass optics capable of revealing the elegance of the night sky. Forget lugging around a hefty telescope - this refractor comes in two easy-to-attach parts, which can be slotted together in a matter of minutes for your observing session.

The Inspire 80Z is supplied with two eyepieces, a 90-degree diagonal, red LED flashlight, a StarPointer Pro finderscope and a free download of the SkyPortal app, ensuring you're fully equipped for your evening under the stars time and time again.

Slewing the telescope is a breeze - it moves slowly up, down and from side to side across the night sky with ease, allowing you to navigate your way to Solar System and bright deep-sky targets with minimum fuss. The Celestron Inspire 80AZ also offers you the chance to try out basic astrophotography with a supplied cap that transforms into a smartphone holder, affording you the opportunity to image your favourite targets.

Tring Astronomy Centre

Congratulations to Jay Locke, who is the winner of the Bresser Solarix telescope and a solar filter

To be in with a chance of winning, all you have to do is answer this question:

Who was the first person to suggest that the Sun is at the centre of our Solar System, instead of the Earth?

A: Isaac Newton
B: Tycho Brahe
C: Nicolaus Copernicus

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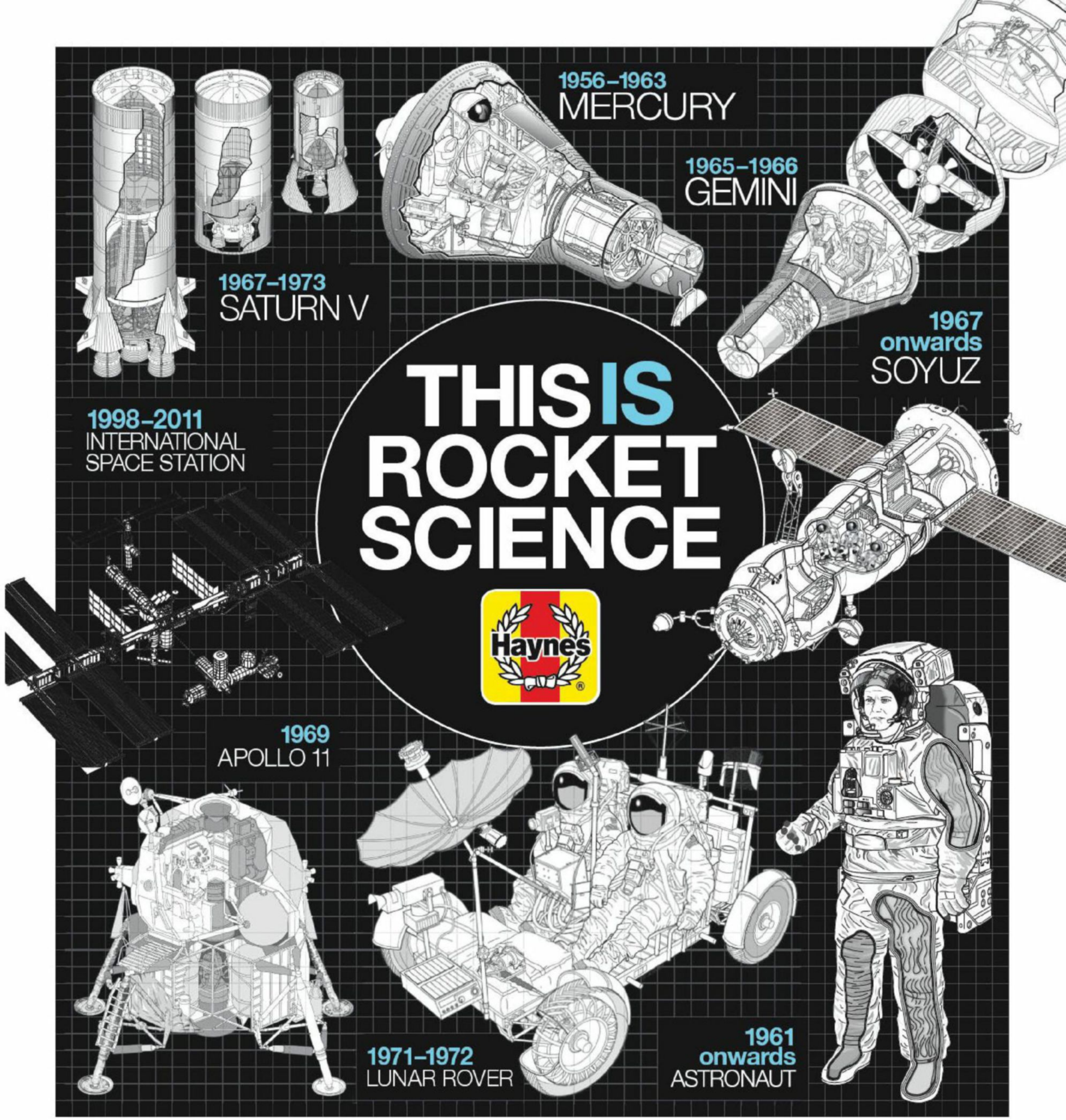

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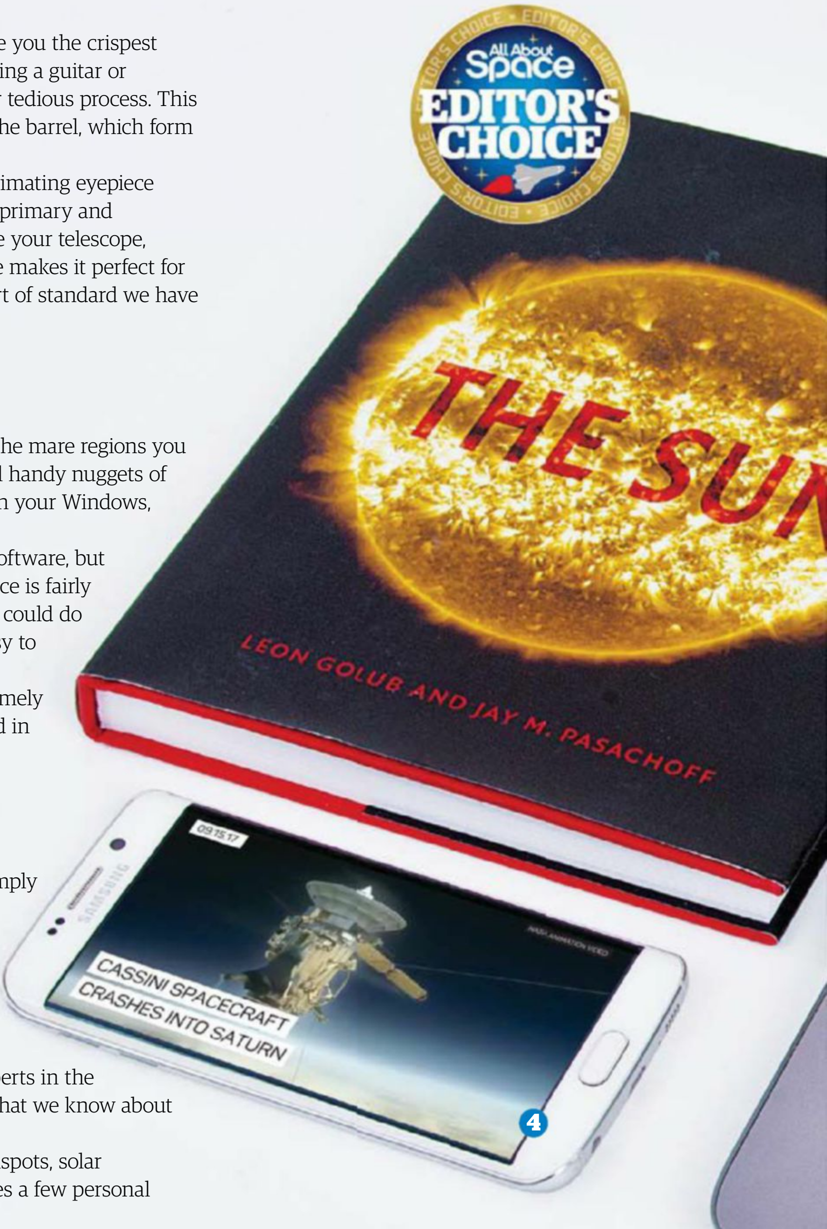
❶ Equipment **Ostara Cheshire Long Collimating Eyepiece**

Cost: £34.99 **From:** Northern Optics

Maintaining your equipment is an essential procedure: it doesn't take long, and will give you the crispest views of the night sky. Collimating your telescope is the astronomical equivalent of tuning a guitar or aligning the steering wheel of your car, but it can be thought of as a time-consuming or tedious process. This particular eyepiece has no lens aspect to it, but it is fitted with two wires at the end of the barrel, which form a crosshair that can be used for the alignment.

After putting the product to the test, it is clear that Ostara's long (1.25-inch barrel) collimating eyepiece makes aligning your telescope mirrors a painless process. It is ideally used for both the primary and secondary mirrors of a Newtonian telescope. If you don't already know how to collimate your telescope, refer to page 86 to find out the full details. The sturdy metallic structure of the eyepiece makes it perfect for several uses, and it could even survive an accidental slip out of the hand. This is the sort of standard we have come to expect of products in the Ostara range.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All About Space
EDITOR'S CHOICE
THE SUN
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CASSINI SPACECRAFT CRASHES INTO SATURN
4

❷ Software **Virtual Moon Atlas**

Cost: Free **From:** www.ap-i.net/avl/

When you look at the Moon with a pair of binoculars or a telescope, can you name all the mare regions you see? Can you spot any craters, and do you know who they're named after? These are all handy nuggets of knowledge to have for the avid astronomer, making this a great programme to install on your Windows, Mac OS X or even Linux desktop.

Created by two passionate astronomers, the Virtual Moon Atlas is a simple piece of software, but is chock-full of useful information regarding all aspects of the lunar surface. The interface is fairly schematic, which could appeal to some users, but for the sake of modern technology, it could do with a brush up. However, that is the only real complaint for this software, as it was easy to install, easy to use and the database is extremely extensive.

This software is completely free and available on different platforms, making it extremely accessible. We would recommend this to anyone who plans to be, or is already, involved in observing the surface of our rugged, natural satellite.

❸ Book **The Sun**

Cost: £25.00 **Publisher:** Reaktion Books Ltd

The Sun is the most influential, powerful and massive body in our Solar System. By simply acknowledging the difference between night and day, it emphasises the Sun's pure dynamism, which is why it's so important to know how it operates. If you enjoyed the Great American Eclipse in August, *The Sun* is a must-buy, as it's suitable for both the scientist and the more 'general' reader.

The authors are Leon Golub, a Senior Astrophysicist at the Smithsonian Astrophysical Observatory in Cambridge, Massachusetts, United States, and Jay M. Pasachoff, a professor of Astronomy at Hopkins Observatory. They are both leading experts in the field of solar physics, so the information is up-to-date and gets into the nitty-gritty of what we know about our nearest star, whilst keeping an enjoyable and engaging prose.

The book covers a range of topics focused exclusively on the Sun, which include sunspots, solar magnetism, seismic waves and even the mysterious corona. We love that it also includes a few personal stories to add humour and a personal insight into the subject matter.

❹ App **Space News**

Cost: £4.99 (approx $6.70) **For:** Android and iOS

Something new always happens in astronomy, whether it is the discovery of a new exoplanet, or the Juno spacecraft uncovering another secret from Jupiter. It can be challenging, trying to keep up with the latest news, but this app does a fantastic job of condensing and customising the latest to suit your personal needs.

Newsfusion Ltd - the creators of this app - pool together news from the world's most popular websites, including NASA, **Space.com** and New Scientist to ensure that the news is interesting, accessible and thought provoking. Obviously, there are several different subtopics, from space exploration to the origins of the universe, some of which may not take your fancy. This is why this app has the option to save your favourite articles and choose your best topics, giving you control of the news you want to read.

There is also a community section to this app. This tab gives users a chance to discuss the latest astronomy and space news with other users - particularly interesting, since any question can provide a handful of different opinions for an engrossing debate.

> "If you enjoyed the Great American Eclipse in August, *The Sun* is certainly a must-buy"

2
Atlas Virtuel de la Lune
Plato 3
3
1

HEROES OF SPACE

Jeffrey Williams

An astronaut, who collected 534 days in space over 16 years

In 2016, Jeffrey Williams broke the record for the most days in space accumulated by an American astronaut, cementing his place as a Hero of Space. Knocking Scott Kelly off this mantle involved participating in four separate space exploration missions, which took roughly 16 years. This included assembling the International Space Station (ISS), and then initiating experiments onboard.

Born on 18 January 1958 in Superior, Wisconsin, United States, Williams didn't have aspirations to become an astronaut as a young boy. This inspiration didn't come until he went to the United States Military Academy in West Point, New York, where he was studying for his engineering degree. At this time he was introduced into the Army aviation, and he read a book called *The Right Stuff* by Tom Wolfe. It was at this is point Williams realised that being an astronaut could actually be possible, and that's what he set as his life goal.

After applying multiple times, Williams was finally accepted to be an astronaut in 1996. From there he had a 9-day stint as the aquanaut commander of the NASA Extreme Environment Mission Operation 3 (NEEMO-3). This operation, along with his previous military experience, prepared him appropriately for his career as an astronaut. This career began in 2000, where Williams spent ten days in space aboard the Space Shuttle Atlantis during the STS-101 mission. This flight consisted of transporting and installing over 5,000 pounds (2,200 kilograms) of equipment and supplies on the uprising ISS. Williams' responsibilities included being the lead spacewalker, with him completing his first spacewalk, lasting nearly seven hours.

©Roscosmos/GCTC

Williams is from a small town in Wisconsin, United States called Winter

In 2006, Williams returned to the ISS for his first long-duration mission. During his six-month stay on the ISS for Expedition 13, Williams saw the arrival of multiple modules and experiments to improve the state of the microgravity laboratory. In September 2006, he returned to Earth aboard the Soyuz TMA-8 with his Russian companion Pavel Vinogradov. When he returned, there must have been a distinct determination to get back on the ISS, and this eventually took another three years. Williams then returned for Expedition 21/22, which was his third and penultimate space exploration mission. These expeditions were focused again on the continued installation of modules, solar panels, experiments and other such equipment.

After this mission, Williams had to be ready when called upon, because he was the backup astronaut to Scott Kelly, who was gearing up to undertake a record-breaking year-long stay on the ISS. However, he was not called upon, and in 2016, Williams returned for his fourth and final trip to space. When he returned, the ISS had been declared completed, but the construction never stopped.

When Williams returned to Earth on 7 September 2016, he had culminated a record-breaking 534 days in space as an American astronaut. This record beat his predecessor, Scott Kelly, by 14 days. Williams also has almost 32 hours of Extravehicular Activities (EVAs) under his belt. Unfortunately since then, the American astronaut Peggy Whitson, who at the time of writing is still currently in space, has broken his record.

> "Williams realised that being an astronaut could actually be possible, and that's what he set as his life goal"

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Sky-Watcher is a First-Class telescope brand offering an incredible range of high-quality astronomical telescopes and accessories, catering for users of all age groups and abilities, from the novice right up to the serious advanced astronomer. Sky-Watcher astronomical telescopes perfectly integrate modern optical technology with precision mechanical engineering, resulting in designs of suberb functionality, versatility and uncompromising levels of performance.

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- Magnifications (with optics supplied): x36, x72, x90, x180
- Highest Practical Power (Potential): x260
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- Telescope Focal Length: 900mm (f/6.92)
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- x2 Barlow Lens
- 30% more Light Gathering than 114mm
- R.A. Motor Drive With Multi-Speed Handset (Explorer-130M only)
- Red Dot Finder
- EQ2 Equatorial Mount
- Aluminium Tripod with Accessory Tray

Explorer-130 Model

Explorer-130M Model illustrated

EXPLORER-130
(Without R.A. Motor Drive)
Prod.Code 10922

SRP £189

EXPLORER-130M
(With R.A. Motor Drive)
Prod.Code 10713

SRP £229

"Every class of object we viewed could be seen clearly... Taking everything into account, this telescope made observing the night sky enjoyable... great views coupled with ease of use."
BBC Sky at Night Magazine

PARABOLIC REFLECTORS – PREMIUM FEATURES

Both the SKYHAWK-1145P & EXPLORER-130P models below offer excellent all-round performance on The Moon, Planets & Deep Sky Objects. They feature premium quality Parabolic Primary Mirrors to eliminate spherical aberrations, producing even sharper, higher-contrast images which are full of detail. A "Paraboloidal" mirror is ground to a complex shape which brings all incoming light rays to a perfect focus, on axis. In addition they feature 0.5mm Ultra-Thin secondary mirror supports, to reduce diffraction spikes and light loss.

SKYHAWK-1145P 114mm (4.5") F/500
PARABOLIC NEWTONIAN REFLECTOR TELESCOPE

- Magnifications (with optics supplied): x20, x40, x50, x100
- Highest Practical Power (Potential): x228
- Diameter of Primary Mirror: 114mm
- Telescope Focal Length: 500mm (f/5)
- Eyepieces Supplied (1.25"): 10mm & 25mm
- x2 Barlow Lens
- Parabolic Primary Mirror
- 0.5mm Ultra-Thin Secondary Mirror Supports
- Red Dot Finder
- EQ1 Equatorial Mount
- Aluminium Tripod with Accessory Tray
- 125% more Light Gathering than 76mm

Prod.Code 10709

SRP £159

"The optics were so good... Captures star clusters and brighter nebulae beautifully... The planet (Saturn) was jaw-droppingly beautiful, with a host of fine detail visible... The review instrument certainly delivered in every important respect."
BBC Sky at Night Magazine

EXPLORER-130P
130mm (5.1") F/650 PARABOLIC NEWTONIAN REFLECTOR TELESCOPE

- Magnifications (with optics supplied): x26 & x65
- Highest Practical Power (Potential): x260
- Diameter of Primary Mirror: 130mm
- Telescope Focal Length: 650mm (f/5)
- Eyepieces Supplied (1.25"): 10mm & 25mm
- Parabolic Primary Mirror
- 0.5mm Ultra-Thin Secondary Mirror Supports
- Red Dot Finder
- EQ2 Equatorial Mount
- Aluminium Tripod with Accessory Tray
- 30% more Light Gathering than 114mm

Prod.Code 10712

SRP £229

"I was most impressed by the views revealed by the 'scope during tests... Despite a phase of nearly 96 percent, the waxing gibbous Moon revealed a seemingly inexhaustible amount of fine detail... Highly recommended!"
Astronomy Now Magazine

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